Methodology, evaluation, simulation and assessment for the analysis of the deployment of DSB and EEIC systems of the FREILOT project Contribution of LET

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Methodology, evaluation, simulation and assessment for the analysis of the deployment of DSB and EEIC systems of the FREILOT project

Contribution of LET

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Executive summary

This report is a synthesis of the contribution of the Laboratoire d'Economie des Transports (UMR 5593 – CNRS, Université Lyon 2, ENTPE, France) to the project FREILOT. This contribution is mainly related to two work packages: Evaluation (WP4) and Deployment (WP6).

In section 1 we introduce the FREILOT project, its aims and main issues.

In section 2, the main contributions to the evaluation methodology are presented. LET focused their contribution in the quantitative evaluation of two systems: Delivery Space Booking (DSB) and Energy Efficient Intersection Control (EEIC). To this, a data collection, analysis and indicators estimation framework for Smartphone-based GPS data was proposed. Those data were completed by DSB and EEIC internal data (respectively from the reservation and utilization records for DSBs and from intersections for EEIC) and by road observations (parking observations for DSB and vehicle counting, both automatic and manual for both systems). The general evaluation framework combining all data collected is also presented here.

In section 3, we focus on the methodological contribution of LET to the deployment work package. The main contributions were made on the methodology of Cost-Benefit Analysis and its applications to each system separately then to a combination of systems. Other contributions to this work package were made to the definition of business models and business cases, and to ensure the data transmission and analysis from the evaluation results' conclusions to feed both business models development and CBA. We present here the different contributions in terms of data exchange and unification and detail the CBA framework developed for the FREILOT project.

Sections 4 and 5 are consecrated to present and discuss results respectively for Evaluation and CBA.

1. Introduction

Transportation of goods is a key enabler for European cities and their economies to maintain their competitiveness but it is also associated to other less positive effects, such as CO2 emissions, air pollution, energy consumption, congestion and noise. Therefore, reduction of fuel consumption, CO2 emissions and emissions of other pollutants is one of the biggest challenges for the cities and for the road transport today.

The FREILOT[1] project targets reduction of fuel consumption and CO2 emissions in urban freight transport. The specific energy consumption of a goods vehicle in urban areas depends on many factors such as vehicle performance, driver behaviour, traffic control strategies and their resulting performance, the vehicle's weight and its load, the urban geography or the road network, among others. Clearly, all of these aspects cannot be addressed by one single solution, (e.g. optimizing the truck engine or providing a better route guidance without considering any other element). For example, an "efficient" truck is not as "efficient" if it needs to stop at every traffic light.

Therefore, the FREILOT consortium has developed a new approach to deal with this issue where four of the above mentioned factors will be addressed:

- Traffic management (intersection control optimised for energyefficiency).
- Vehicle (Acceleration and adaptive speed limiters).
- Driver (Enhanced "eco driving" support).
- Fleet management (Real-time loading/ delivery space booking).

The basic idea is that cities will give priority at traffic lights, on certain roads or during certain times of the day, to the trucks that follow FREILOT scheme. The trucks eligible for this would be equipped with acceleration/speed limiters and eco-driving support for the drivers. In addition, a delivery space booking system will be made available for those trucks in order to avoid double parking or "drive around the block" behaviour.

All four elements present in the pilot would be contributing to the reduction of the fuel consumption and reduction of emissions of CO2 and other pollutants.

The main goal of the pilot is to show that up to 25% reduction of fuel consumption in urban areas can be achieved through FREILOT scheme. The FREILOT scheme was piloted in four European cities: Bilbao (Spain), Helmond (Netherlands), Lyon (France) and Krakow (Poland) between November 2010 and October 2012, and counted several participants from different countries and sectors: public authorities, vehicle manufacturers, ICT providers, research institutes, consulting companies and transport carriers, among others.

The Laboratoire d'Economie des Transports (UMR 5593 – CNRS, Université Lyon 2, ENTPE, France) participated in the project, contributing mainly to four work packages: Development (WP2), Operation (WP3), Evaluation (WP4) and Deployment (WP6). Since the contributions of LET to WP2 and WP3 were of expertise and follow-up nature, and those of WP4 and WP5 methodological, scientific and technical, we will focus on those two last work packages.

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[1] Urban Freight Energy Efficiency Pilot, Information and Communications Technologies Policy Support Programme (ICT PSP). Information Society and Media Directorate. Grant agreement no.: 238930. Pilot type B.

This report is organised as follows, Section 2 is dedicated to methodological contribution to the evaluation framework, i.e. to WP4. Section 3 focuses on methodological contribution to WP6, mainly on Cost-Benefit Analysis. Finally, Sections 4 and 5 are consecrated to results presentation and discussion for tasks 4.2 (evaluation analysis and results) and task 6.4 (CBA).

2. Contribution of LET to evaluation methodology

2.1. *Data collection schema and scenarios*

At the beginning of the project, it was envisaged to have a common data collection schema to retrieve and store all data coming from the four FREILOT sites (Bilbao, Lyon, Helmond and Krakow) to the CTAG central database[2]. An overall vision of this schema is presented bellow:

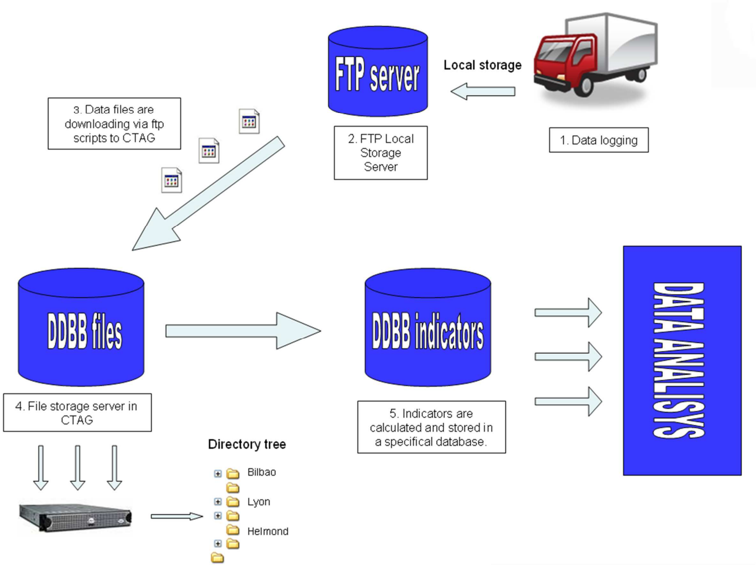

Figure 1 – Data management scheme (Blanco et al., 2010)

The data is logged from the data logger devices during the 12 months of experiment and stored locally in the FTP servers managed and supervised by the test site leaders. It's important to note that the work of the DAS systems is different depending on the test site and service so the data collection schema may differ in each location.

Periodically the data files are going to be downloaded and saved in the CTAG central database. This process has to be done automatically so the development of automated downloading scripts is needed to facilitate this task. After the files collection, the rest of the evaluation process will start, i.e. data processing, performance indicators calculation, hypothesis testing and global assessment (Blanco et al., 2010).

During the process for the definition of the data acquisition system, three main tasks were carried out:

1. Preparation of the data list with the measures that can be provided for each datalogger system. Different data loggers were used (for each system and application case, see Blanco et al., 2010, 2012).
2. Definition of the different file formats where the logs are saved. Main issues in this task are the name of the files (to avoid duplicate names), file format (text files) and data arrangement inside these files (this is an important point for the later evaluation tools development).
3. Data storage schema. This task is focused in the identification of the data servers that will store the files locally and the downloading scripts development to automate the

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[22] CTAG is the partner of FREILOT project coordinating the evaluation and then the data collection and processing procedures.

data retrieval from the data sources (pilot sites) to CTAG database.

These tasks have to be sorted out with the partners in charge of the implementation work package and in the four pilot sites where the five FREILOT functionalities has to be installed. LET being involved in the evaluation of two systems (EEIC and DSB), we focus here on both of them. More precisely, ant taken into account the test sites, 4data collection devices will be considered taken into account the specificities of the pilots:

1. **Intersection Control** in Helmond and Krakow.
2. **Intersection Control** in Lyon.
3. **Delivery Space Booking** in Bilbao.
4. **Delivery Space Booking** in Lyon.

Next table summarizes the five existing scenarios per test site and system:

System Test site	EEIC	DSB
Lyon	Scenario 3	Scenario 5
Helmond	Scenario 2	
Krakow	Scenario 2	
Bilbao		Scenario 4

Table 1 – Summary of data acquisition scenarios

2.1.1. Scenario 2: Intersection Control in HELMOND and KRAKOW

Intersection Control has two DAS which will register data: a vehicle unit collecting GPS data and sending it to the road unit when the vehicle is on radio range of an intersection, and a road side unit collecting data related with the traffic light controller status on intersections. The road side unit stores the truck and intersection logs and compresses the data into one file. These files are retrieved to the Peek headquarter where CTAG will be able to download them later.

Concerning the form of data transferred and processed, we will use two files containing the data logged with the intersection control system. The file name pattern is the same commented in the previous scenario with Volvo systems (see section 9.2.1.2). Some variations depending on the particularities of each DAS were introduced. In this case, there are two files per intersection, one of them containing the data logs coming from all the trucks which have been crossing the intersection during the day and the other with info about the traffic controller state per day. Then these two files are compressed into another one. The name proposed for these three files are the followings:

- "yyyy-mm-dd_IDCity_x_IDSystem_y_IDIntersection_xx.gz". For the compressed file being:
    - "yyyy-mm-dd" the date where the file is created.
    - "x" : city ID: 2→Bilbao, 3→Lyon,4→Helmond,5→Krakow.
    - "y" : system ID: 1→IC, 2→SL, 3→AL, 4→EDS, 5→DSB.
    - "xx" is the intersection ID. It could be an alphanumerical code, not defined yet.

Example of name: “2010-10-15_IDCity_3_IDSystem_1_IDIntersection_A1.gz”

- “yyyy-mm-dd_IDCity_x_IDSystem_y_IDIntersection_xx_TruckLogs.txt”. For the file containing the truck logs. An example of file name in Lyon could be:

  “2010-10-15_IDCity_3_IDSystem_1_IDIntersection_A1_TruckLogs.txt”

- “yyyy-mm-dd_IDCity_x_IDSystem_y_IDIntersection_xx_IntersectionLogs.txt”. Containing the infrastructure logs.

  For example:
  “2010-10-15_IDCity_3_IDSystem_1_IDIntersection_A1_IntersectionLogs.txt”.

2.1.2. Scenario 3: Intersection Control in Lyon

In Lyon test site the data provided by the Intersection control data loggers is recorded on trucks per day. There are two different test sites which their proper priority mode of operation:

1. Green wave
2. Priority control with cooperative system

In both test sites the trucks will register the data logs only when they enter in the test area. For the green wave test site, FREILOT trucks will detect that they are entering in the test zone using GPS positioning.

For both intersections (priority control mode/green wave mode), there will be one file per truck and day (if trucks cross the test areas) containing the data described in the previous section. There will be another file containing data registered by the traffic density sensors installed in the test sites.

The name of the files follows the same pattern that have been defined previously:

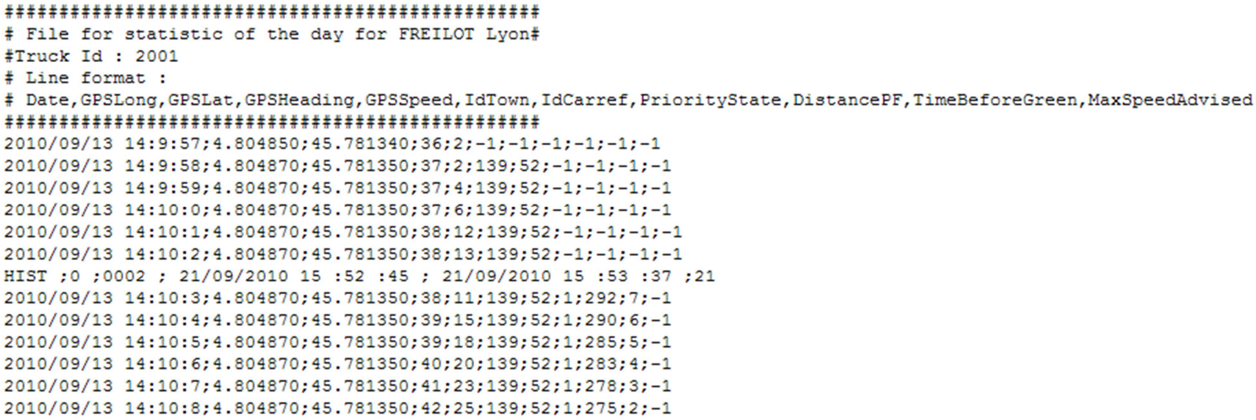
- “yyyy-mm-dd_IDCity_x1_IDZone_x2_IDSystem_y_IDTruck_z_IDCompany_w.txt“
  Where :
    - “yyyy-mm-dd“ is the date where the data contained is logged .
    - “x1“ : Id of city : Lyon 3.
    - “x2“ : Id of area, Route de lyon (cooperative priority) = 0, Gerland (green wave) = 1.
    - “y“ : Id of system , for the Intersection Control is 1.
    - “z“ : Id of truck (ex. truck 1 : 2001, truck 2 : 2002, truck 3 : 2003)
    - “w“ : ID of company.

The files have a header which contains line beginning by "#" and describing:

1. Id of the truck which the file comes from.
2. Description of the data fields.

File name example:
“2010-10-28_IDCity_3_IDZone_0_IDSystem_1_IDTruck_2001_IDCompany_DHL.txt“

An example of file logged for truck identified as “2001“ that is approaching to the intersection controller “VN052” looks as follows :



```
#################################################
# File for statistic of the day for FREILOT Lyon#
#Truck Id : 2001
# Line format :
# Date,GPSLong,GPSLat,GPSHeading,GPSSpeed,IdTown,IdCarref,PriorityState,DistancePF,TimeBeforeGreen,MaxSpeedAdvised
#################################################
2010/09/13 14:9:57;4.804850;45.781340;36;2;-1;-1;-1;-1;-1;-1
2010/09/13 14:9:58;4.804870;45.781350;37;2;139;52;-1;-1;-1;-1
2010/09/13 14:9:59;4.804870;45.781350;37;4;139;52;-1;-1;-1;-1
2010/09/13 14:10:0;4.804870;45.781350;37;6;139;52;-1;-1;-1;-1
2010/09/13 14:10:1;4.804870;45.781350;38;12;139;52;-1;-1;-1;-1
2010/09/13 14:10:2;4.804870;45.781350;38;13;139;52;-1;-1;-1;-1
HIST ;0 ;0002 ; 21/09/2010 15 :52 :45 ; 21/09/2010 15 :53 :37 ;21
2010/09/13 14:10:3;4.804870;45.781350;38;11;139;52;1;292;7;-1
2010/09/13 14:10:4;4.804870;45.781350;39;15;139;52;1;290;6;-1
2010/09/13 14:10:5;4.804870;45.781350;39;18;139;52;1;285;5;-1
2010/09/13 14:10:6;4.804870;45.781350;40;20;139;52;1;283;4;-1
2010/09/13 14:10:7;4.804870;45.781350;41;23;139;52;1;278;3;-1
2010/09/13 14:10:8;4.804870;45.781350;42;25;139;52;1;275;2;-1
```

Figure 2 – Example of file registered in Lyon with the Intersection control data logger.

2.1.3. Scenario 4: Delivery Space Booking in Bilbao

For the DSB in Bilbao the data is logged from each truck and day taking advantage of a Blackberry’s GPS system. The driver logins to the Blackberry’s system before starting the journey and then the GPS data is collected for the whole journey. Files are sent via GPRS to the Bilbao local FTP server.

The data files in Bilbao will contain the data recorded per truck and delivery route (one truck can follow different routes per day). The names of the files are defined following the next pattern:

- “yyyy-mm-dd hh_mm_ss_IDCity_x_IDSystem_y_IDTruck_z_IDDriver_w_IDCompany_j_n_m.txt”

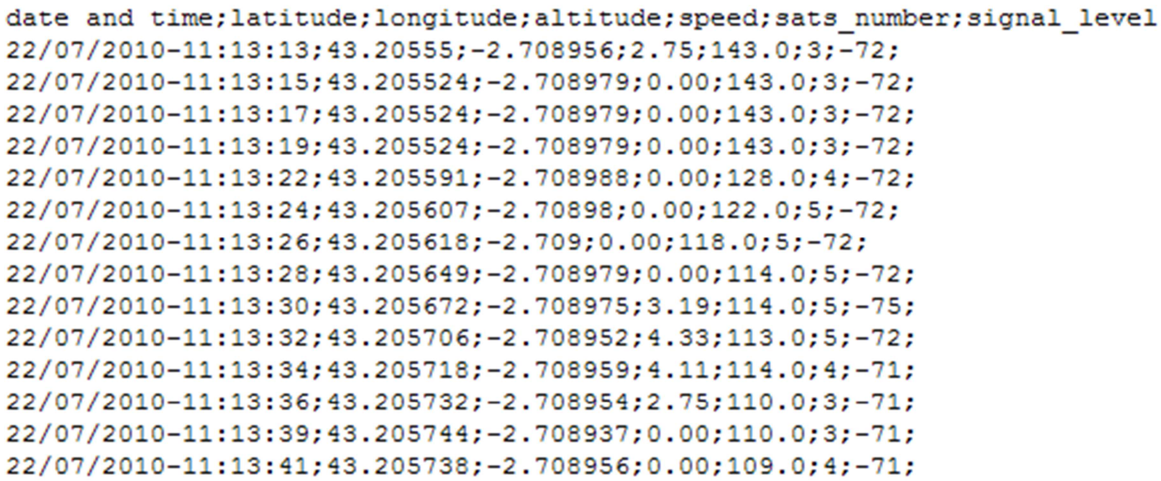
  Where:

  - “x” : city ID: Bilbao 2.
  - “y”: system ID: DSB 5.
  - ”z”: truck ID: plate number of the truck.
  - “w”: driver ID: login of the driver.
  - “j”: company Id: name of the company which owns the truck.
  - “n” “m”: files are fragmented because of size problems, “n” references the particular part from the total number of parts “m”.

For example, in Bilbao using the DSB during a day, being the file the first part of a total of six, the name is as follows.

- “2010-07-22 07_49_08_IDCity_2_IDSystem_5_IDTruck_0624BCN_IDDriver_perez_IDCompany_DHL_1_6.txt”

An example of data file recorded in Bilbao is presented in the next picture:



```
date and time;latitude;longitude;altitude;speed;sats_number;signal_level
22/07/2010-11:13:13;43.20555;-2.708956;2.75;143.0;3;-72;
22/07/2010-11:13:15;43.205524;-2.708979;0.00;143.0;3;-72;
22/07/2010-11:13:17;43.205524;-2.708979;0.00;143.0;3;-72;
22/07/2010-11:13:19;43.205524;-2.708979;0.00;143.0;3;-72;
22/07/2010-11:13:22;43.205591;-2.708988;0.00;128.0;4;-72;
22/07/2010-11:13:24;43.205607;-2.70898;0.00;122.0;5;-72;
22/07/2010-11:13:26;43.205618;-2.709;0.00;118.0;5;-72;
22/07/2010-11:13:28;43.205649;-2.708979;0.00;114.0;5;-72;
22/07/2010-11:13:30;43.205672;-2.708975;3.19;114.0;5;-75;
22/07/2010-11:13:32;43.205706;-2.708952;4.33;113.0;5;-72;
22/07/2010-11:13:34;43.205718;-2.708959;4.11;114.0;4;-71;
22/07/2010-11:13:36;43.205732;-2.708954;2.75;110.0;3;-71;
22/07/2010-11:13:39;43.205744;-2.708937;0.00;110.0;3;-71;
22/07/2010-11:13:41;43.205738;-2.708956;0.00;109.0;4;-71;
```

Figure 3 – Example of file registered in Bilbao with the DSB data logger.

2.1.4. Scenario 5: Delivery Space Booking in Lyon.

Delivery Space Booking in Lyon might have the same data collection schema for non Volvo trucks as it has been considered in Bilbao, this is data logging based in GPS measures from mobile devices in non Volvo trucks. Data files will contain the data from each truck per day. The data list, data files definition and naming is not closed yet but it might be very similar to the considerations made in Bilbao too.

2.1.4.1.Data list recorded

As it was mentioned before data list features will be very similar to Bilbao, the possible measures are finally in the next table:

Delivery Space Booking	RANGE	UNITS	Logging frequency
GPS date and time	-	YYYY-MM-DD HH:MM:SS	0.5 Hz
GPS position	-	GPS position	0.5 Hz
GPS speed	-	Km/h	0.5 Hz
GPS number of satellites	-		0.5 Hz
GPS signal level	-	dB	0.5 Hz

Table 2 – List of data registered by DSB system in Lyon

2.1.4.2.Files definition

The file name pattern proposed for Lyon files regarding the DSB system is described bellow, depending on some considerations need to be taken it's possible that some information indicated could change.

- "yyyy-mm-dd hh_mm_ss_IDCity_x_IDSystem_y_IDTruck_z_IDDriver_w_IDCompany_j.txt"

Where the different fields will contain the same information commented in the previous sections. Files would be registered per truck and day.

2.1.4.3.Local Data Server

Local data server or the back office systems are not defined yet.

2.2.Database

This chapter describes the data management process from the data acquisition systems to the final results.

In this case there will be different locations where the data is collected (Bilbao, Helmond, Lyon and Krakov). But for storing data is recommendable to have a centralized database. This implies that this database must be in a fix place and it should have enough capacity for storing all the data collected during the 12 months of pilot. For FREILOT, the proposal is to have the centralized database in CTAG (Vigo) where the first analyses will be carried out.

The data storage server has capacity enough to store the files coming from the different test sites during the experiment. With the global data base centralized in one location, the data files sharing between the evaluation partners will be more effective. Then rest of the process continues with the performance indicator calculation, hypothesis testing and data global assessments.

2.3.Model and methodology for estimating environmental impacts of tested systems

In order to estimate fuel consumption and gas emissions, a methodology is proposed that can use two variants of the data logger system (for a more detailed description about the different dataloggers see Blanco et al., 2010):

- VOLVO trucks datalogger
- GPS based datalogger (used in non-VOLVO trucks)

After a brief survey on the main methods and software used for fuel consumption and environmental impact of freight transport, two types of models were identified. The first uses average values for speeds and accelerations, and it is mainly used for overall greenhouse gas emissions for transport (cf. ARTEMIS, 2005a, b). The methods belonging to this category use in general synthetic equations, often resumed on tables like those of COPERT and Impact ADEME software solutions. The second is able to estimate instantaneous fuel consumptions and emissions (cf CMEM User_Guide_v3.01d SCORA G and al.).

In next figure, the complete process for fuel consumption and CO_2 emissions calculation is presented:

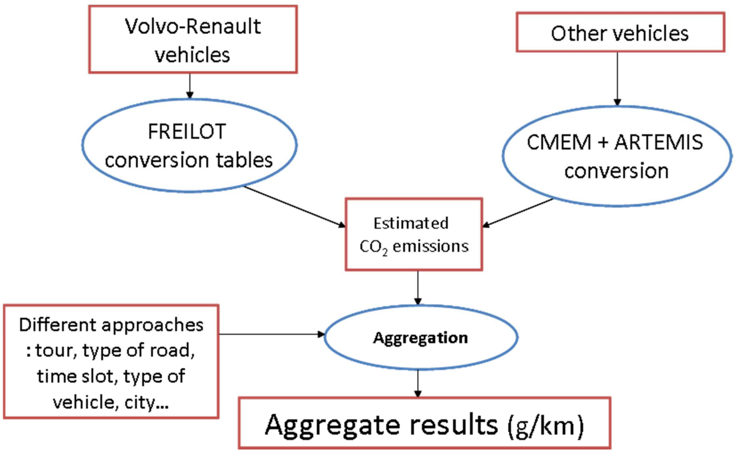


Figure 4 – Evaluation of environmental impacts

For Volvo trucks, instantaneous fuel consumption will be recorded directly from the vehicle. Then, by aggregating the data (using conversion tables), it is possible to obtain the total fuel consumption.

For non-Volvo trucks, the fuel consumption will be estimated using an instantaneous model as the CMEM software. The main input parameters are instantaneous speed, instantaneous acceleration, motor type, weight and power of the trucks. Before this estimation, the data recorded with this data logger is going to be processed in order to identify possible bugs, clean the GPS data and track the delivery stops. For this operation, specific software is going to be developed and adjusted. The next figure shows the process to estimate the indicators from the GPS data:

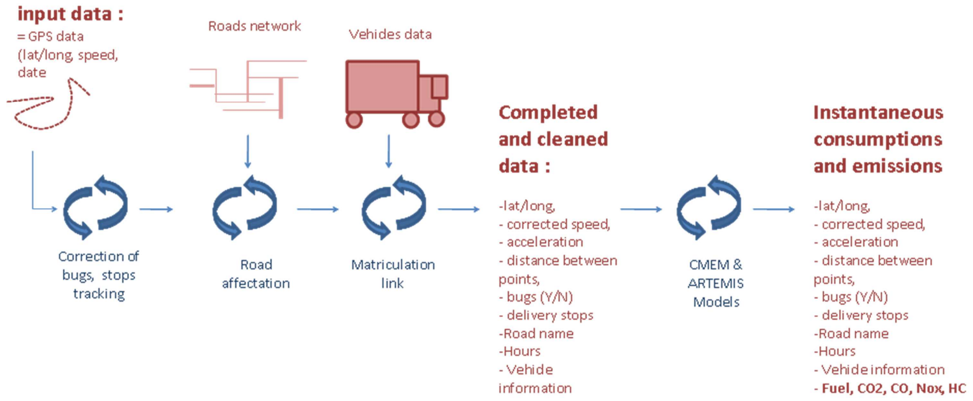


Figure 5 – Calculation of fuel consumptions and pollutants emissions for non-Volvo/non-Renault vehicles

According to many authors, fuel consumption and CO_2 emissions are proportionally related (Shimizu and al., 1996). Moreover, as the CMEM software has been calibrated with a similar hypothesis, the relationship coefficient between fuel consumption and CO_2 emissions can be obtained. In addition, we use an European model as ARTEMIS to calibrate the CMEM's estimated values.

2.3.1. Choice of models

The non-Volvo trucks are used for IC and DSB tests and Evaluation. Several models exist in order to estimate consumptions and emissions. However, only few models answer to these constraints :

- the chosen models must take into account accelerations , specifically for IC evaluation. Indeed, we expect that the reducing of consumptions will be due to the reducing of accelerations/deceleration ;
- The model must take into account several types of vehicle because the studied system concern the light-duty vehicles (<3,5T) as well as the heavy vehicle (around 16 T) ;
- The tool must be quick because of the quantity of collected data.(several billons of GPS points). Moreover, we must be able to automate the estimation in a computing program with command lines.

The set of vehicles which participate to the experimentation is not representative of the variety of vehicles used for Urban Goods Movement. However, one of the objectives of FREILOT is to be able to generalize the results of the Evaluation to an real European context. The approach that we have chosen is to try to apprehender the generalisation work during the evaluation period. Following this principle, a literature search has been made. The methods used in Europe are either for general traffic issues (ADEME, 2003; ARTEMIS, 2005a,b; Gkatzoflias et al., 2007; Melios et al., 2009) or derive from industrial models developed for specific vehicle models and subjected to confidentiality clauses. The general models are public and propose several types of vehicles, both light and heavy, but are only related to the speed and to a typology of average-loaded vehicles. We found only two models that take explicitly into account both speeds and accelerations in the variable set for fuel consumption and pollutant emissions estimation. Akcelik et al. (2003) propose a model mainly used in the Australian context for private cars. Although the equations can be reproduced and adapted, no calibration on heavy vehicles has been made. Barth et al. (2004) propose a model for the USA context that includes both cars and heavy vehicles.

It is for these all reasons that we have chosen the CMEM model (Barth et al., 2004) to estimate fuel consumptions and pollutants emissions according to the instantaneous acceleration, instantaneous speed and some vehicle parameters as the weight. Nevertheless, the CMEM is not fully satisfactory because it is an American Model which take into account badly the European norms. Therefore, two solutions were possible to calibrate the CMEM estimation with European references. The first solution is to use some real measures from the tested vehicles. The process is long and complex, the vehicles are not very representative of the European fleet, and the difficulty of the process does not allow to be representative of all urban situations (small/large street, different type of traffic, meteorology…) . The second solution is to use existent models that give emissions for different category of vehicles (based on weight and Euro norm) according to the average speed in urban conditions. Two models are famous in European transportation research : COPERT and ARTEMIS. Today, COPERT model take into account :

- the hot and cold emissions (which depend on the motor temperature) ,
- different driving conditions
- climatic conditions

Each model is calibrated with a large data set of vehicles (for more details about these models, see Gkatzoflias et al., 2007 and ARTEMIS, 2005a,b).

Between COPERT and ARTEMIS, there are some difference of methodology and vehicle data set but both give emissions according to speed . The results can be more or less different but are in the same order of magnitude, mainly for CO2 and NOx Emissions. The differences can be more important for HC, CO, and PM10.

2.3.2. Choice of measures to estimate

The CMEM model is able to estimate fuel consumption and CO2, CO, NOx and HC emissions. However, the PM10 emissions do not appear among the possible measures to estimate with this model. COPERT and ARTEMIS are able to estimate estimate fuel consumption and CO2, CO, NOx, HC and PM10 emissions.

Fuel consumption and consequently CO2 emission estimation with the CMEM is robust and realistic. Indeed, after several tests on the baseline data, the aggregated average estimations with the CMEM model are close to those obtained with COPERT and ARTEMIS models. For this reason, fuel consumption and CO2 will be estimated using the CMEM model then calibrated using the method presented in next subsection.

NOx and CO estimations will also be estimated using a calibrated CMEM adaptation (see below) because although there are some differences between COPERT and ARTEMIS the first calibrations results are satisfying. This was not the case of HC, which variability in each model and the smaller contribution to air pollution with respect to NOx led us to not take into account this measure in the FREILOT evaluation.

PM10 would be interesting to estimate, but we are confronted to two main limits. The first is that the CMEM model do not allow to estimate the instantaneous PM10 emissions, which suppose to produce only aggregate data without a connection to the acceleration behaviour. In this way, the effects of intersection control on acceleration will not be highlighted in PM10 emission estimation. The second is that for the moment, there is no robust model for PM10 estimation, and the main frameworks present many methodological and fundamental differences which seem to converge on the fact that the best analysis seems to be a study on acceleration behaviour, and not on PM10 emission rates, since these two elements are extremely correlated. For this reason, we do not propose an explicit PM10 estimation in the FREILOT evaluation.

2.3.3. Calibration process

The first tests for the FREILOT Evaluation have made with CMEM+ARTEMIS Evaluation because of the easy availability of ARTEMIS equations. Because CMEM parameters are numerous and difficult to get from carriers, we made three categories of vehicle. For each group, in order to calculate the coefficient factor between CMEM and ARTEMIS, we used the CMEM’s instantaneous emissions recorded on about 50 delivery routes.

During the project, if we have more elements for the choice between ARTEMIS and COPERT, we will define if we keep CMEM+ARTEMIS or if we use CMEM+COPERT.

3. DSB infraction, delivery practices and traffic data collection method

In order to estimate the impacts of DSB systems on both traffic flows and driver's parking behaviour, we propose a data collection method based on both automatic and manual data collection method

3.1. Background

Automatic data collection methods: main tools, strong points, limits (add table)

Manual data collection methods: main tools, strong points, limits

3.2. The proposed method – general issues

We propose a method that is able to collect data that will be used to compare the DSB impacts with respect to a reference situation (baseline) on two sites (Bilbao and Lyon, then to compare both analysis between them. The available resources, both technological and human, are not the same for each pilot site. Moreover, the geographic areas (Bilbao DSB perimeters are bigger than those chosen on Lyon and Bilbao DSB sections contain in general groups of street types whereas those of Lyon are small one-sense sections). For these reasons, the method is adapted to each pilot site.

3.2.1. Research questions, hypothesis and type of data to be collected

The main research questions related to delivery space booking deal with impacts on traffic efficiency, in particular those related to traffic flow influences (RQ8-4). The hypothesis that cannot be verified using neither the GPS data collection nor the questionnaires are the following:

All these hypothesis need a deep understanding of the traffic context and the parking and transit behaviour. The best way to make it is to combine a quantitative and a qualitative analysis. After examining the existing literature and studying the context of the DSB pilot sites (respectively Bilbao and Lyon) we identified the data that would be used to make these analysis.

The quantitative data that will be used is of two types: first, traffic counting data are needed to define the baseline in terms of traffic levels. For this, automatic and manual data collection methods will be developed. Also a counting procedure able to collect both quantitative and qualitative data to characterise the transit and parking practices near the delivery spaces will be implemented.

3.2.2. Data collection procedures

The automatic data collection procedure will be implemented only in Bilbao because of the costs. In Bilbao, automatic sensors are still installed near three of the four DSB places, so no costs for using these data are charged. In Lyon, no sensors are available in the proposed DSB areas, so specific caption tools would be installed. After regarding the advantages and disadvantages of manual and automatic procedures, we propose a manual method for Lyon, that is able to estimate traffic in small time slots (every 10-15 minutes). Manual counting is also used in Bilbao to validate automatic counting and to define traffic state in the area where no sensors are installed.

For manual data collection methods, different protocols have been made in Lyon and Bilbao. In Bilbao, a manual counting of traffic at the intersections during 5 minutes every half an hour has been followed in Bilbao for the baseline. Instead, for the pilot, no manual counting is envisaged, but traffic analysis will rely on only automatic counting data.

In Lyon, a specific manual counting method has been applied. Two surveyers have been positioned, one per site, from 7h to 13h. Traffic is countered each 10 minutes, continuously.

For transit and parking behaviour data collection, a first questionnaire has been applied on Bilbao (see ANNEX 1). This questionnaire provides aggregated data about infractions, and has been modified in order to provide more detailed information. However, during the baseline, the first questionnaire gave correct results, but not the second (formularies of this second approach were not well filled in). Finally, the pilot data collection follows a more detailed questionnaire derived from that retained with some changes based on the formulary of Lyon.

In Lyon, a detailed questionnaire has been developed. Because the areas are small, each vehicle is individuated, then its parking behaviour is recorded according to several variables (see ANNEX III). In this questionnaire, the physical location of the vehicle, the type of parking (mainly related to an infraction or a delivery space usage practice), the arrival and departure hours, and other information related to the parking behaviour are written.

3.2.3. Chart of the evaluation procedure

The evaluation procedure follows the chart detailed in figure XX

1. Baseline data collection (Different for each site)
2. Baseline characterisation
3. First intermediary data collection
4. Intermediary evaluation analysis
5. Second intermediary data collection
6. Definitive evaluation analysis

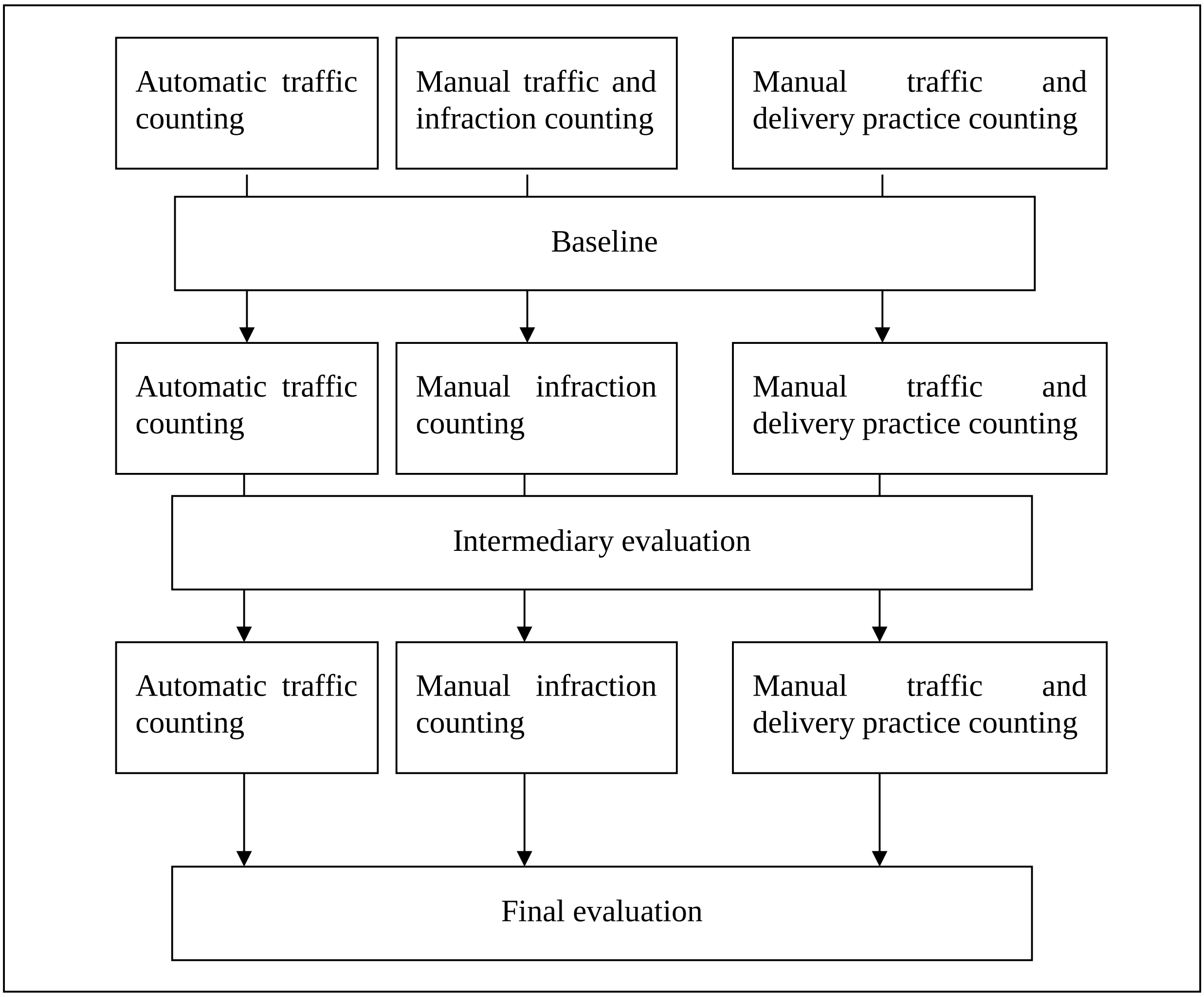


Figure 6 – Chart of the evaluation procedure

3.3. Bilbao pilot site

3.3.1. Automatic data collection methods

In Bilbao, four DSB areas are taken into account. However, only three of them are equipped with automatic traffic counting sensors. These sensors are installed at streets near the crossfire sections, in order to estimate the traffic intensity in each road, direct or indirectly. Indeed, not all the streets are equipped by sensors, but only a subset of them. In order to obtain the traffic in the unequipped streets, we can estimate them by addition and/or subtraction of the flows of the adjacent streets that are equipped.

3.3.2. Manual data collection methods

The manual data collection has been carried out using two types of questionnaire for the baseline and an improved questionnaire derived from that of Lyon in the case of the pilot (see appendix …). The baseline data collection would take place during 6 weeks whereas for the pilot we propose to collect data of 3 complete weeks.

3.4. Lyon pilot site

The method in Lyon has been developed from Bilbao’s feedbacks. After determining the advantages and disadvantages of the procedure used in Bilbao, and the impossibility to automatically measure the traffic flows in the two DSB areas, we propose an « only manual » data collection method. This method is able to collect more detailed qualitative data but needs more human resources to ensure its accuracy.

3.5. Evaluation plan

3.5.1. General

Baseline (2-3 months) → A defined number of weeks: manual data collection. For Bilbao, automatic traffic counting is available for all the baseline period.

Pilot (9 months)

Intermediary

> Bilbao: Manual data collection (1 person): 3-4 complete weeks per site. Period: March-June 2011
>
> Lyon: Manual data collection (3 people): 3-4 complete weeks per site. Period: June-July 2010

Final

> Bilbao: Manual data collection (1 person): 3-4 complete weeks per site. Period: September-December
>
> Lyon: Manual data collection (3 people): 3-4 complete weeks per site. Period: October-November

3.5.2. Bilbao pilot site

6 weeks baseline (at least 4 complete weeks per site)

20 weeks pilot (3 complete weeks per site)

3.5.3. Lyon pilot site

4 weeks baseline (at least 3 complete weeks per site)

8-10 weeks pilot (8 complete weeks per site)

4. LET contribution to deployment analysis

4.1.Main contribution of LET

The main contribution of LET to the WP 6 (deployment) was mainly related to its skills in transport economics and more precisely on cost-benefit analysis methods. LET coordinated the task 6.4. (Development of a cos-benefit analysis of all systems), by proposing a methodology of simulation of deployment scenarios in terms of costs and benefits (at an economic, environmental and social viewpoint), by coordinating the different simulations, by being the interface between the evaluation and the cost-benefit analysis, and by transposing the conclusions of the Cost-Benefit Analysis in the business cases developed to analyse the possible business model of those systems' deployment.

The FREILOT project has been carried out between March 2009 and September 2012 with a main focus on demonstration and deployment. Five technological solutions have been implemented and tested in four European cities, enabling services that are related to four service domains covering the entire delivery operation scope. We focus on one domain, the fleet management, which related service is a delivery space booking system (DSB); it gives the possibility to plan the deliveries, by reducing travel times, improving traffic flow conditions and therefore, reducing energy consumption and working time for delivery execution.

Different stakeholders can be interested on such services provisioning and exploitation. Two main goals have been identified (Zubillaga et al., 2012) for involving service provisioning:

- *Public Goal*: Administrations, like cities or other road authorities, are the Service Direct Users or customers, in the EEIC and DSB services.
- *Private Goal*: Depending on the FREILOT service analysed, the technology providers will be the Service Providers (VOLVO, RENAULT Trucks, PEEK, GERTEK) and the Fleet Operator will be the Service Direct Users in all 5 FREILOT services.

The FREILOT project has been carried out between March 2009 and September 2012. It is focused not on pure or applied research but in the phases of demonstration and deployment. For that reason, 5 technological solutions have been implemented and tested in four European cities, enabling services that are related to four service domains covering the entire delivery operation scope. The domains and service related to each of them are summarized in the following:

- **Traffic management domain**
  - *Service 1: Intersection Control Optimised for Energy Efficiency (EEIC):* The FREILOT freight distribution vehicles get moderate priority when they approach the intersection, this increases non stopping and improves the traffic flow and energy consumption. At the same time, they get information about the traffic light phases (when it will be in red, green...) and therefore, drivers can adapt their speed. This facilitates an active collaboration and interaction between vehicles and traffic light management systems, as the drivers could adapt their speed and reduce stops, improving also city's road security.
- **Vehicle operation domain**
  - *Service 2: Acceleration and Adaptive Speed Limiters (AL & ASL)*: The service solution proposed in FREILOT gives the possibility to define geographical zones to facilitate adaptive vehicle speed or acceleration limitation. This can be done by the fleet operator or by the city council in order to regulate the access and the accessibility conditions of certain areas of the cities, such as pedestrian streets or limited traffic zones, among others.

- **Driver behaviour domain**
    - *Service 3: Enhanced "Eco Driving" Support (EDS):* The solution adopted in FREILOT, promotes efficient driving, reduces emissions and noise pollution by reducing non-ecodriving behaviours like rapid acceleration, noise and fuel consumption, and thereby also emissions.
- **Fleet management domain**
    - *Service 4: Delivery Space Booking (DSB)*: The service solution proposed in FREILOT gives the possibility to plan the deliveries, by reducing travel times, improving traffic flow conditions and therefore, reducing energy consumption and working time for delivery execution. This service will provide the basis for enhancing the use of city delivery facilities by the existing distribution demand and therefore will improve the service supplied by the city.

Different stakeholders can be interested on such services provisioning and exploitation. Two main goals have been identified (Zubillaga et al., 2012) for involving service provisioning:

- *Public Goal:* Administrations, like cities or other road authorities, are the Service Direct Users or customers, in the EEIC and DSB services.
- *Private Goal:* Depending on the FREILOT service analysed, the technology providers will be the Service Providers (VOLVO, RENAULT Trucks, PEEK, GERTEK) and the Fleet Operator will be the Service Direct Users in all 5 FREILOT services.

In order to study the deployment issues of such service enabling technologies, it is important to craft the necessary environment and context to bring these services to real life operation of the city. To do this, a business model is needed. A starting point for building the business model is the selection of target market segments. This model describes the value that is delivered to customers, how customers are being charged, and what business context and processes need to be built in order for the business to be successful. On the other hand the identification of all possible barriers for the deployment of the services will be listed and linked to potential solutions. For understanding the value to stakeholders it is necessary to understand what the individual benefits of each service are and what is needed to bring and keep them alive and profitable. It is then important to provide a consequent cost benefit analysis to support the business model and help decision makers find arguments and solutions to the identified barriers. Finally, an exploitation plan describes the induction of the business and how to sustain and expand the business. One pillar of the plan is the certification and regulatory actions that need to be performed.

This comes down to the following structure for the business model strategy, where overall process and specific work is listed (Zubillaga et al., 2012). In this paper, we will focus on cost benefit analysis and on deployment enablers and barriers for two systems, i.e. DSB and EEIC). For an in-depth description of the business model and the analysis of all systems, including the combination of two or more services, see Zubillaga et al. (2012), Jeftic et al. (2012), Aifandopoulou et al. (2012) and Gonzalez-Feliu et al. (2012).

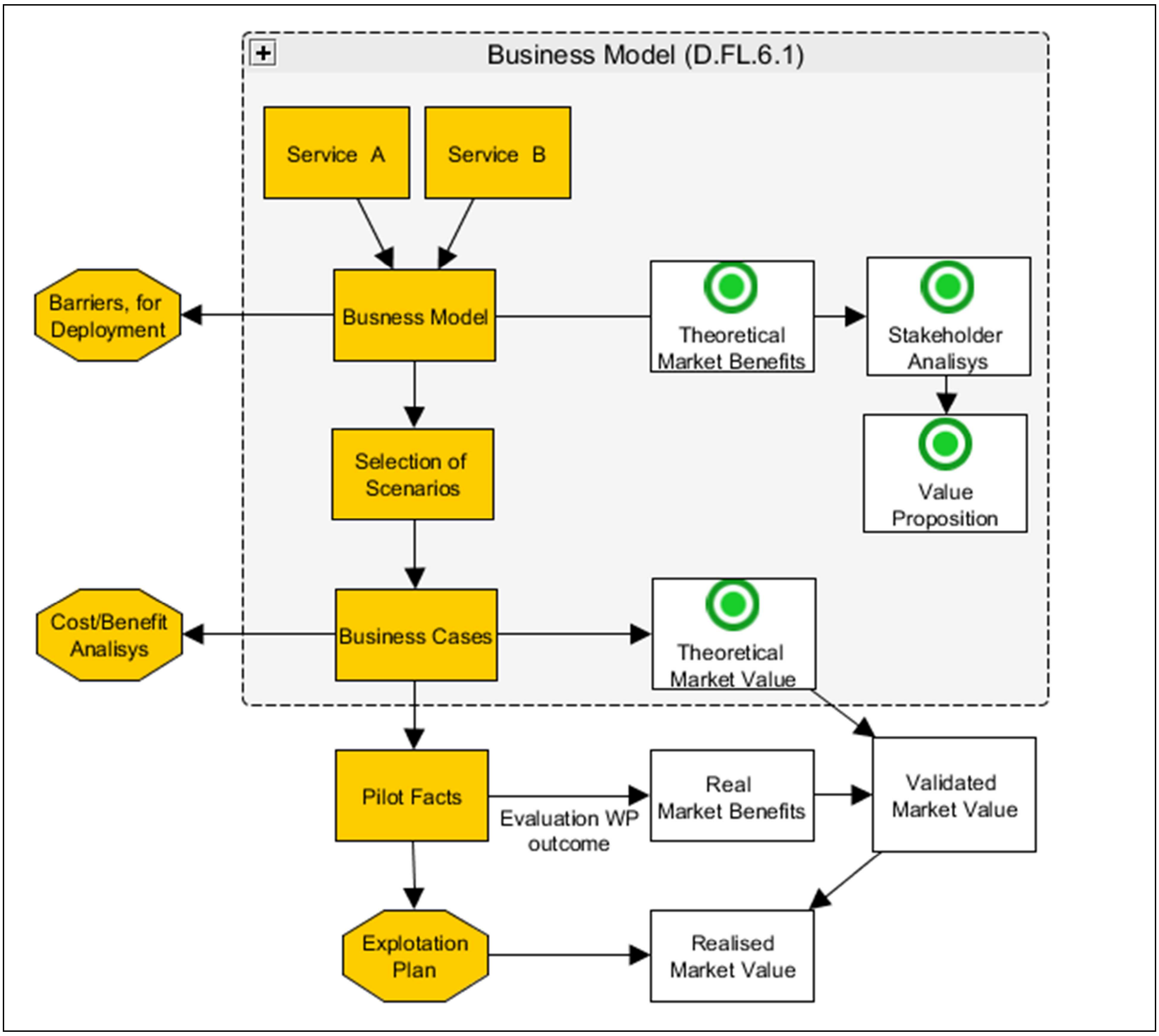


Figure 7 – Pilot process and deployment strategy chart (Zubillaga et al., 2012)

4.2. *Method and hypotheses*

The cost benefit analysis (CBA) is the most used economic calculus tool for assessing the deployment of strategies in different fields (Boardman et al., 2006). CBA provides a protocol for assessing the efficiency impacts of proposed policies. The patterns for the CBA are derived from standard CBA methodologies (for a review and CBA patterns, see DG REGIO, 2008). Cost-benefit analysis are practical ways of assessing the desirability of projects, where it is important to take a long view (looking at repercussions in the further, as well as the nearer, future) and a wide view (allowing for side-effects of many kinds on many stakeholders and/or areas). In other words, it implies the enumeration and evaluation of all the relevant costs and benefits. This involves drawing on a variety of traditional sections of economic study-welfare economics, public finance, resource economics-and trying to weld these components into a coherent whole. For those reasons, we will develop a cost-benefit analysis derived from the method proposed by DG REGIO (2008).

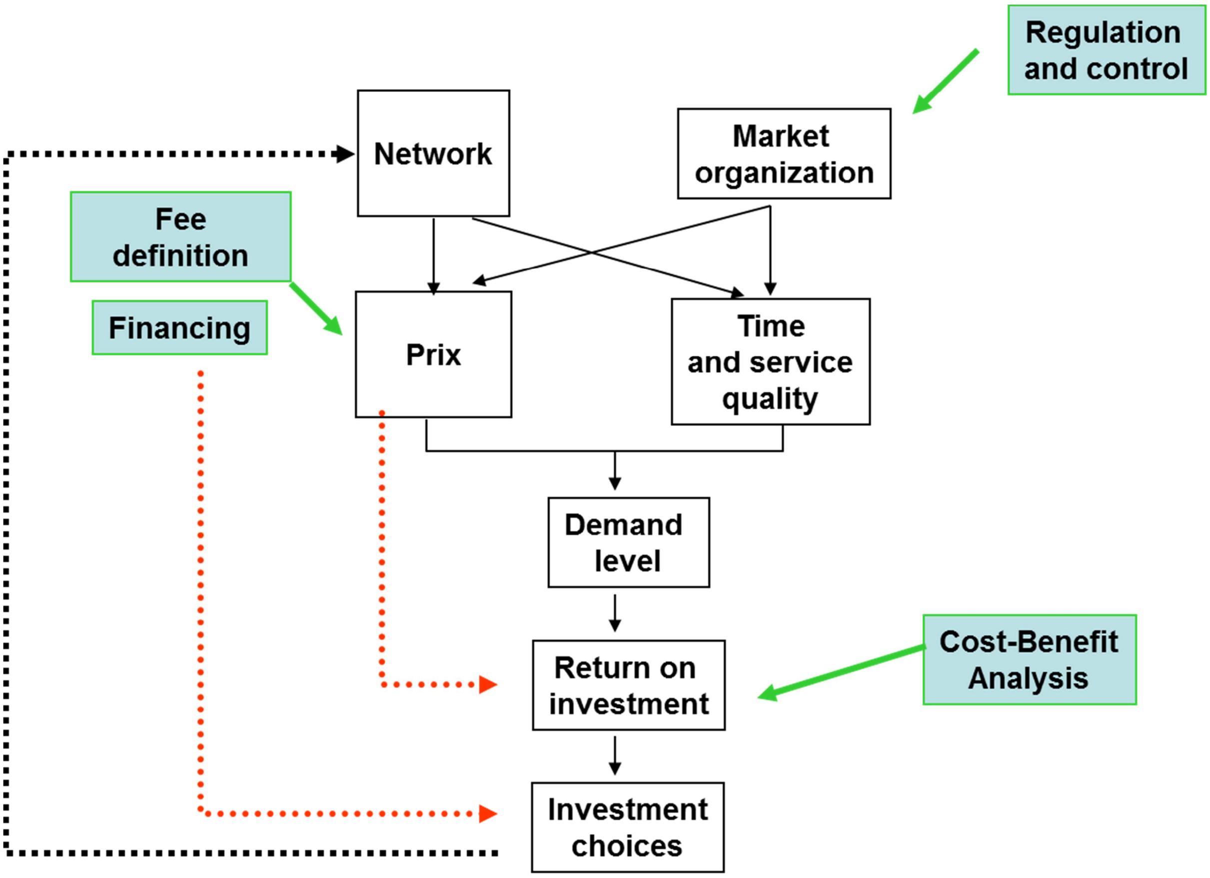


Figure 8 – Position of Cost-Benefit Analysis (CBA) on the transport market command mechanisms (Source: Bruno Faivre d'Arcier and Alain Bonnafous, Laboratoire d'Economie des Transports)

The analysis of return on investment is usually made via CBA methods (Bonnafous and Tabourin, 1995). However, such analysis must be conditioned to the definition of quantitative objectives. Moreover, it is made on the hypothesis of a status change with respect to a reference situation (Business as Usual, or BAU). In other words, to make a CBA it is necessary to define a reference situation, which will be the projection in a BAU configuration of the current situation (i.e. a forecasting image of the current situation to a near o middle-term horizon). Then, two complementary assessments are needed. First, the estimation and assessment of the impacts that the new device or solution has on the current system; second the identification of the favouring and limiting factors to the deployment of the device or solution. The first assessment concerns this deliverable, and the second is detailed on deliverable D.FL. 6.3 (Deployment barriers and solutions).

4.2.1. General notions of a Cost-Benefit Analysis methodology

Cost-benefit analysis belongs to the family of quantitative economics methods. A CBA framework often consists on a middle or long-term simulation (and assessment) of an investment strategy and its refunding mechanisms. To do this, it is important to first identify all costs of such strategy: those costs include all investments (strategic planning costs) as well as all tactical and operational costs, year after year, for a given time horizon. In general this horizon is set to 10 years for infrastructure projects (DG REGIO, 2008). Once costs are identified and quantified (we insist on the fact that CBA are quantitative analysis, belonging to the quantitative economics field), it is needed to identify and quantify benefits in the same time horizon. After that, all costs and benefits are converted into a monetary value.

In order to take into account the pluri-annual time horizon, it is important to define an updating rate "a" which allows comparing two quantities of money at two different periods. Taking the value of a quantity of money V_t at time t, and V_n the value of this quantity at horizon n, they are related by the following equation:

$$V_t = Vn/(1+a)n$$

Then, year by year, benefits are confronted to costs and their difference is updated using an update rate of 4%. Finally, an Investment Return Rate (IRR) is calculated, in a 10-year horizon.

The analyses are iteratively repeated for different configurations for two main aims: one is to identify the sensitive variables (see the different sensitivity analyses in the results section), the other is to find the most suitable system's configurations to ensure a suitable IRR, i.e. to make sure the investments are not lost. Moreover, two main type of analyses are made, one only on the economic and monetary values (economic analysis) and another taking into account the non-fee benefits (socio-economic analysis) to examine the suitability of the chosen configurations for different stakeholders involved on the FREILOT device deployment and operational use.

For more information about the general method, see DG REGIO (2008).

4.2.2. Main hypotheses and assumptions

Although each technology has different settings and is associated to specific assumptions and hypotheses, we need to define a set of common assumptions to all scenarios in order to compare and assess them. The general hypotheses are associated to the way the money is obtained to invest and to the stakeholder that is making investments.

In FREILOT, the different pilot tests are made in different cities (in terms of number of inhabitants, surface, demographic characteristics, cultural elements, etc.) and each system is not tested in all cities. To make a rigorous and scientific analysis, deployment needs to be analysed on the same comparative basis. We can suppose that cities are different and it is important to take this into account when simulating the deployment of FREILOT devices. However, it is also important to start on a comparable basis and then extend those results to other contexts. To do this, we propose to make a complete analysis on a virtual city, which has the characteristics of several medium European areas, then to extend the results to cities of other characteristics, making a direct link to the tested device; for example, the city's discriminant characteristics for EEIC are not the same than for DSB, so the typology of cities will be adapted to the assessed FREILOT device.

That city has been simulated by extracting the characteristics of several medium French urban areas, all having a very dense city centre (hypercentre) and a more and more spread land distribution when the eccentricity of neighbourhoods or suburbs increase. Data is combined and made anonymous to simulate an urban area which characteristics are similar to the main medium urban areas in Europe. The details of the virtual city creation can be seen in MODUM (2012). Then, to not penalise city planners of small areas, we propose to transpose the results when applicable to situations that can be adapted to their areas, characterising the main benefits to allow them repeat such analysis. We stress on the fact such analysis are indicative and need to be repeated to any real area, the conclusions of these deliverables having to be considered as guidelines to see how such technologies can be deployed.

We assume a VAT of 20% and, for each system personnel fees equal to those of employees working during the pilot implementation, operation and evaluation phases (in case of pilots in different cities, the retained costs will be précised in the corresponding section).

We assume the investor is a public authority, mainly a city, and the money to invest is available. If the public authority needed to loan it, interest rates should be added to the CBA, but as a first approach the assumption of money availability let the various readers have a first idea of rentability without complicating the analyses. Another important assumption concerns the time period where investments are made. Oppositely to public transport infrastructures (tramways, subways, urban-suburban trains), investments are not made in the first two years, but the systems are introduced gradually. This assumption enforces that of money availability.

The CBA will be made on a 10-year horizon, which is enough long to ensure a return of investment and enough short to not need a strong technology change or replacement during the operation period. We also assume the level of operating costs and revenues as constant over this period.

The discount rate is assumed to be the French public one, i.e. 4%. This rate varies from one country to another, and can be updated (as well as personnel costs and VAT) when adapting the scenario assessment to cities of one precise country.

Last but not least, we suppose that the target IRR (internal return rate, i.e. the return on investment level requested by the investor) is that of the French public sector, i.e. 4%. If the CBA takes into account a private investor, the IRR is set to 15%.

All simulations are based on the same city, a virtual 2.000.000 inhabitants urban area created from real data (MODUM, 2011). Using the tools of evaluation in this context, i.e. generalising local effects to a city point of view, we estimate the costs and the benefits for the two main stakeholders: the city (or the collective community) and the transport carriers (or individuals).

5. Evaluation results

5.1. *EEIC*

5.1.1. Analyses Methodology

Helmond, Lyon and Krakow have developed a method to optimize the traffic in the intersections. In each case, the EEIC is adapted to the control local systems.

In Helmond, a network control system based on massive vehicle detection with inductive loops is developed. FREILOT introduces the Cooperative Technology with an OBU in the vehicle and a RSU in the traffic controller. Thus, the RSU can provide priority to an approaching vehicle in function of its length or identification (D.FL.2.1 Implementation plan).

In Lyon, the applied traffic management strategy employs a method with cooperative dynamic exchanges between trucks (equipped with a HMI) and intersections controllers. It is only valid for FREILOT trucks equipped with an OBU.

In both cases, the first step to process the data is to unzip GPS files from the RSUs and import to R software. It is important, in a previous analysis, to identify traffic directions, validate speeds, calculate distances between two points, calculate the distance before/after traffic lights, identify stops at traffic lights (when 60 m before the traffic light the vehicle speed is 4 km/h) and finally delete the rounds on which there are less than 4 crossings at traffic lights.

5.1.2. Results in Helmond

The pilot site of Helmond (Figure 9) consists of a two-way road with a length of 6 km and a perpendicular secondary road. There are 13 intersections with tricolour traffic lights resulting on 38 stop lines. The average distance between two traffic lights is 500 m. These intersections are all connected in an adaptive urban traffic control system (UTOPIA) which is augmented with Cooperative Technology at strategy locations and to adequate it to long vehicles.

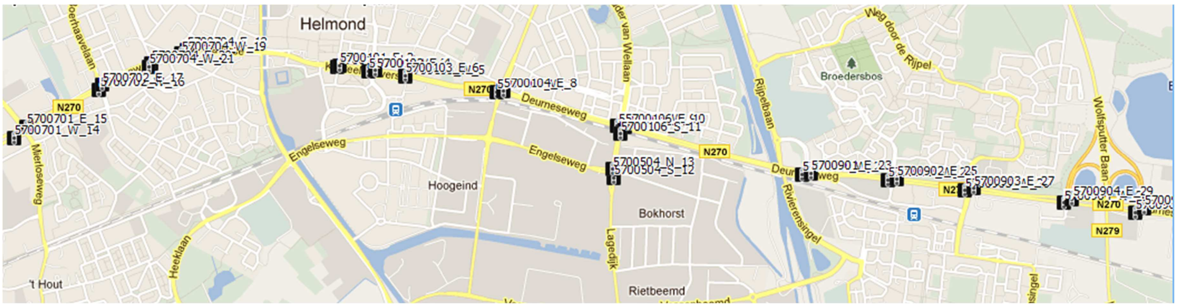


Figure 9 – Characteristics of the pilot area of Helmond for EEIC.

It makes use of Van den Broek vehicles, from UTOPIA, and also of the fire brigade vehicles. The reasons for using the intersection control in the freight transport carriers are related to economic and environmental reasons whereas in the fire brigade are related to safety reasons. Data from fire brigade vehicles are not processed for two reasons. The first is that the benefits for fire brigades are security and not fuel consumption, and the second is that fire brigade vehicles are always crossing a fire, even if it is red, when using the system, so they could disturb the results since they measure data mainly when attending emergency situations. Moreover, the quantity of data from fire brigade in baseline is under the statistical threshold to produce significant results.

All long the pilot period, a regular check of the evaluation results has led to identify several dysfunctions and exceptional events. For instance, a storm disturbed the system in three intersections between April and June 2011. For this reason, a part of the results have been invalidated and a second baseline has been made. In this report the results of the two baselines and the last pilot period are showed. The two baselines have been grouped under the same flag (Table 3).

Period	Number of trips	Number of distinct vehicles
Baseline	66	13
Pilot	52	10

Table 3 – Characteristics of the non fire brigade trucks.

Figure 10 shows the number of intersections with which a truck crosses. It can be seen that, in most cases, the trucks do not complete the full route.

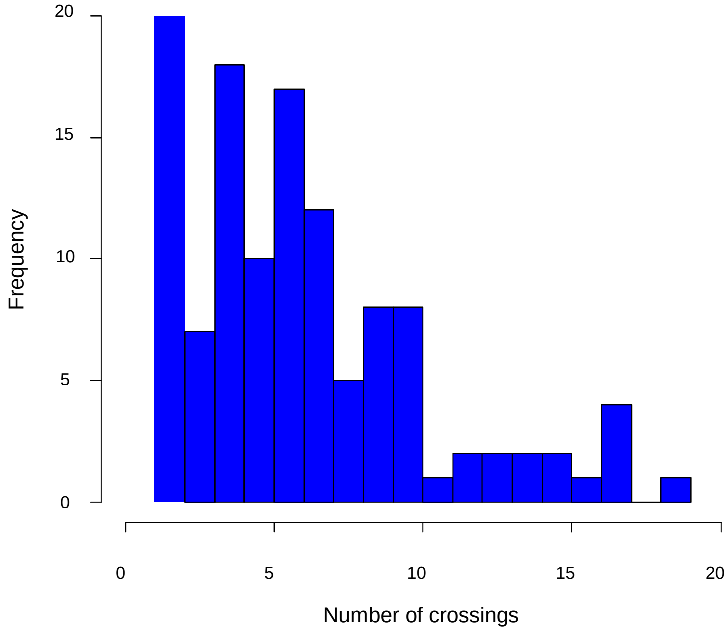


Figure 10 – Distributions of the number of crossings per route.

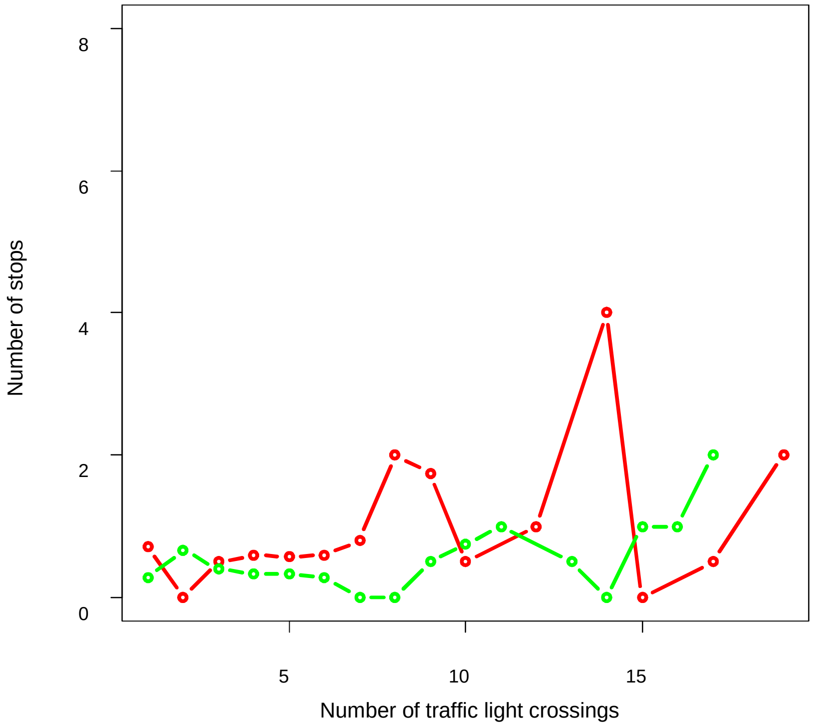


Figure 11 Number of stops per number of traffic light crossings (baseline in red and pilot in green).

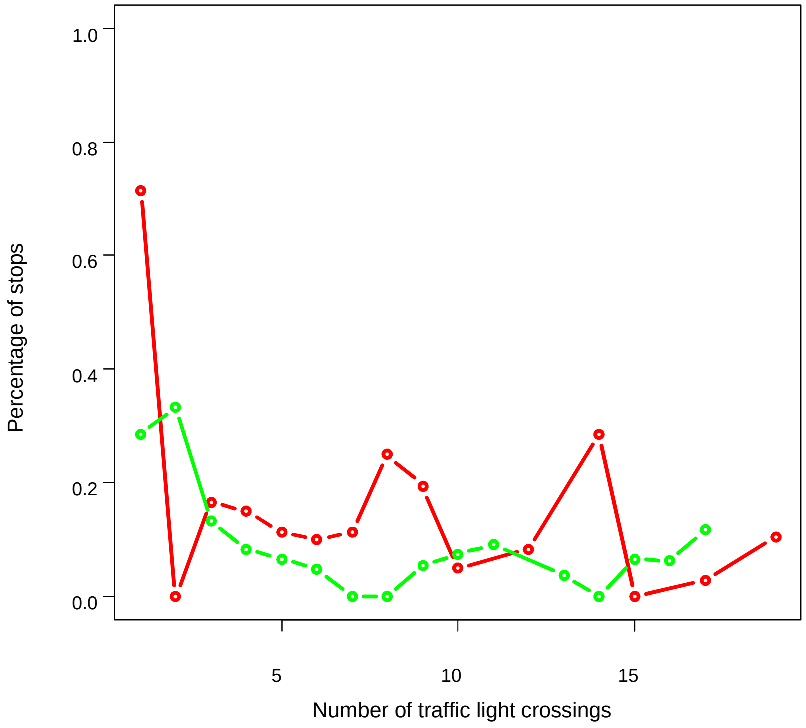


Figure 12 Percentage os stops per number of traffic light crossings (baseline in red and pilot in green).

Figure 11 and Figure 12 show the number of stops with respect to the number of crossings.

The introduction of EEIC has a positive effect since the mean number of stops decreases. The difference is appreciable between 7 and 9 crossings. For instance, Figure 11 shows that when the vehicle goes through 8 traffic lights stops in two of them in the baseline period (Figure 12 shows that the probability to stop is near 25%) but does not stop in any of them in the period pilot. Over 10 crossings, the data sample is very small, so it can not be concluded about the potential of EEIC in these cases.

Period	**Number of crossings**	**Number of stops**	**% of stops**
Baseline	408	52	13%
Pilot	343	20	6%

Table 4 Number of crossings and stops in both periods.

Table 4 reports the mean number of stops. It is observed in the pilot period a percentual gain of 62% with respect to the baseline. Nevertheless, the probability to stop at a traffic light is already low during the baseline (about 1 stop each 8 crossings) what illustrates the good synchronisation between lights in the city of Helmond, specially in the urban area of the FREILOT site. As shown by Figure 10, each route crosses a different number of intersections, which means that some trips do not need to stop and others stop several times.

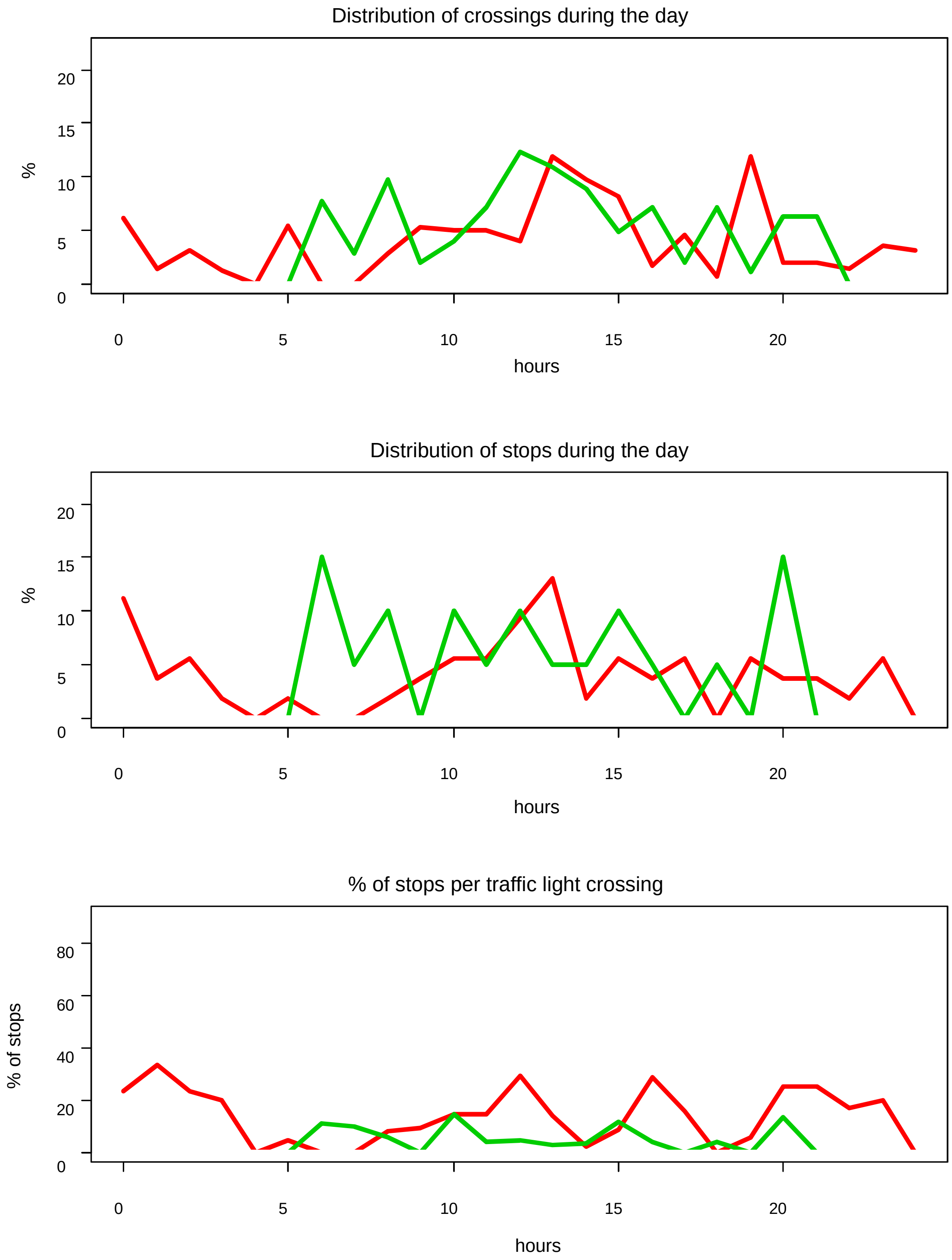


Figure 13 Temporal distributions of crossings, stops and percentage of stops during the day (baseline in red and pilot in green).

The temporal distribution during the day (Figure 13) presents few changes (except between 5h and 9h). Most of the observations are between 11h and 17h. The same trend is applicable to the number of stops (which depend on both the temporal distribution and the traffic status, which is external). Indeed, in car traffic peak hours (5h - 9h) the number of stops increases considerably. Concerning the percentage of stops per traffic light, it is observed that it decreases during the pilot. Moreover, the variability is lower during the pilot.

Using the CMEM model on the GPS data (collected at each second) we can estimate the average instantaneous speed as well as the average fuel consumption and emissions within the influence area of each intersection (100 m before and 60 m after the intersection). The calculation method is similar to that of DSB evaluation and is detailed in the evaluation methodology and in Pluvinet et al. (2012). The following table shows geometric average results for all fires

	Baseline	**Pilot**	**Rate of change**
CO_2 emissions (g/km)	644	562	-13%
NO_x emissions (g/km)	3.87	3.33	-14%
Fuel consumption (l/100km)	24	21	-13%
Speed (km/h)	35	36	+2.6%

Table 5 Emissions, consumption and speed.

We observe an average gain of 13% approximativelly for fuel consumption and emissions, with an average increase of only 2.6 km/h. However, the differences are important from one intersection to the other. For that reason, results are also presented in a disaggregated way, by intersection:

Table 6 Fuel consumption, CO_2 Emissions and speed, by intersection.

	Baseline		Pilot		Fuel consumption			CO2 emissions			Speed		
Intersection	Nb vehicles	Nb stops	Nb vehicles	Nb stops	Baseline	Pilot	Variation	Baseline	Pilot	Variation	Baseline	Pilot	Variation
5700101_W_1	21	5	21	5	27,6	22,1	-19,9%	746	602	-19,3%	30	35	16,7%
5700102_W_3	19	2	19	2	21,3	19,1	-10,3%	581	542	-6,7%	27	29	7,4%
5700103_E_6	15	1	15	1	27,4	19,5	-28,8%	730	530	-27,4%	41	44	7,3%
5700103_W_5	19	0	19	0	23,8	11,6	-51,3%	653	330	-49,5%	37	34	-8,1%
5700104_E_8	15	0	15	0	23,5	21,2	-9,8%	637	579	-9,1%	40	29	-27,5%
5700104_W_7	20	2	20	2	28,1	27,5	-2,1%	778	765	-1,7%	13	15	15,4%
5700106_W_9	16	1	16	1	32,1	30,5	-5,0%	858	811	-5,5%	37	39	5,4%
5700701_W_14	2	0	2	0	28,4	28	-1,4%	733	744	1,5%	40	49	22,5%
5700702_E_17	11	2	11	2	17,4	15,9	-8,6%	476	433	-9,0%	31	39	25,8%
5700702_W_16	15	2	15	2	15,6	24	53,8%	419	651	55,4%	39	34	-12,8%
5700704_E_18	17	2	17	2	24,5	21,9	-10,6%	661	589	-10,9%	38	38	0,0%
5700704_E_20	11	1	11	1	20,7	20,8	0,5%	563	562	-0,2%	38	34	-10,5%
5700704_W_19	15	1	15	1	22,2	18,5	-16,7%	604	498	-17,5%	31	39	25,8%
5700704_W_21	15	1	15	1	21,9	16	-26,9%	584	435	-25,5%	41	37	-9,8%
5700901_E_23	11	0	11	0	20,7	29,3	41,5%	567	783	38,1%	37	42	13,5%
5700901_W_22	9	1	9	1	23,3	25,1	7,7%	626	669	6,9%	38	49	28,9%
5700902_E_25	14	2	14	2	16,4	14,5	-11,6%	441	392	-11,1%	37	46	24,3%
5700902_W_24	9	0	9	0	19,9	24,7	24,1%	531	664	25,0%	49	47	-4,1%
5700903_E_27	12	2	12	2	36,8	26,8	-27,2%	993	728	-26,7%	34	39	14,7%
5700903_W_26	9	1	9	1	23,5	17,3	-26,4%	629	456	-27,5%	44	35	-20,5%
5700904_E_29	9	2	9	2	25,9	14,1	-45,6%	690	389	-43,6%	41	51	24,4%
5700904_W_28	7	1	7	1	29,3	30,5	4,1%	774	810	4,7%	40	51	27,5%
5700905_E_31	5	0	5	0	10,1	1,6	-84,2%	273	45	-83,5%	59	68	15,3%

5.1.3. Results in Lyon

Route de Lyon and Jean Jaurés Avenue are the chosen road to pilot the EEIC in Lyon. Route de Lyon has two separate roads, with two lanes on each, and also a double lane bus road in the middle. The bus lanes benefits from specific priority at the signals. It has 3600m length with 9 tricolor traffic lights. In Summer 2011 one more traffic light was added by Grand Lyon's planning issues and the FREILOT project was adapted to this new situation. The distance between two lights is about 400m.

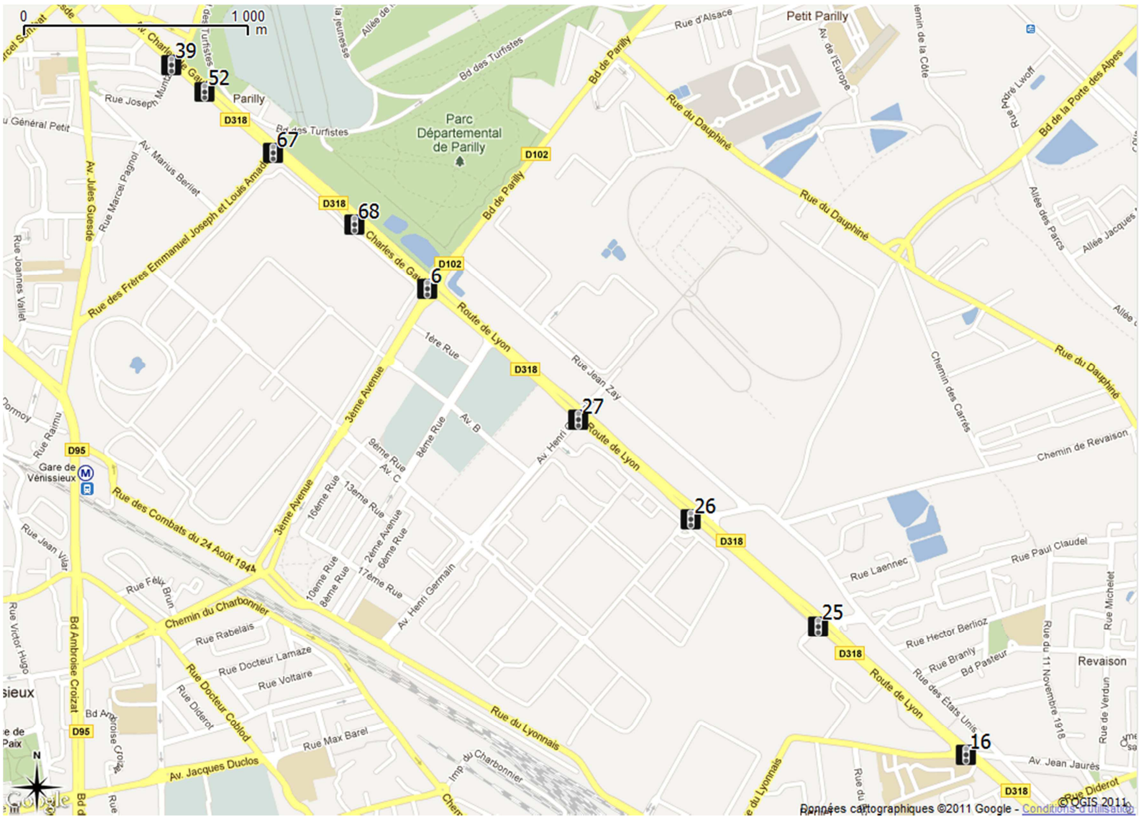


Figure 14 Street area and direction of analysis (initial configuration).

Figure 15 Street area and direction of analysis with an addittional traffic light, after Summer 2010.

Two vehicles are concerned on this evaluation. The first one is a garbage vehicle that presents the particularity that it makes very regular routes: one daily in the morning making the same path. Moreover, this vehicle was present during all the data collection periods. The second one is a classic LTL transport vehicle which has been added during the Pilot 3 period.

Table 7 shows the distribution of traffic lights per period and Table 8 the number of collected routes per vehicle. It is observed that almost all routes cross over all traffic lights. For this reason, it is kept for the analysis only routes crossing o ver all traffic lights to make the results homogeneous and easier to compare and understand.

Period	Date	Number of traffic lights	Number of traffic lights connected to trucks
Baseline 1	From 10/12/2010 to 20/04/2011	9	0
Pilot 1	From 21/04/2011 to 30/06/2011	9	9
Pilot 2	From 01/07/2011 to 02/10/2011	10	9
Pilot 3	From 03/10/2011 to 13/03/2012	10	10
Baseline 2	From 14/03/2012 to 14/04/2012	10	0

Table 7 Number of traffic lights during each test period.

Period	Garbage vehicle	LTL transport vehicle
Baseline 1	39/39	
Pilot 1	61/61	
Pilot 2	78/78	
Pilot3	43/48	5/6
Baseline 2	38/42	2/8

Table 8 Number of routes crossing over all traffic lights with respect to the total number of collected routes.

Most routes happen between 5:30h and 6.30h (about 95%), which confirms the regularity of the garbage truck. In addition, the same driver drove the truck during almost all the time of data collection. At this time period of the day, no congestion and a fluid traffic is observed in the section, which positions the pilot in a “best case” situation.

It can be identified, for each crossing, if the truck stopped or not at the traffic light. Table 9 reports the average number of stops per route during each test period. It is observed that the introduction of the collaborative EEIC system leads to a reduction of 1 stop (pilot 1 with respect to baseline 1 and pilot 3 with respect to baseline 2). Moreover, the addition of the new light had at the beginning few impact (Figure 16 - Figure 17) because it took place in summer, corresponding to the Scholar holidays. Note that on this section there is a regular traffic of scholar buses at similar hours which has priority.

Period	Number of stops per route	Percentage of stops
Baseline 1	4.15	46.2%
Pilot 1	2.97	33.0%
Pilot 2	2.97	29.7%
Pilot3	3.55	35.5%
Baseline 2	4.50	45.0%

Table 9 Average number of stops per route during each test period.

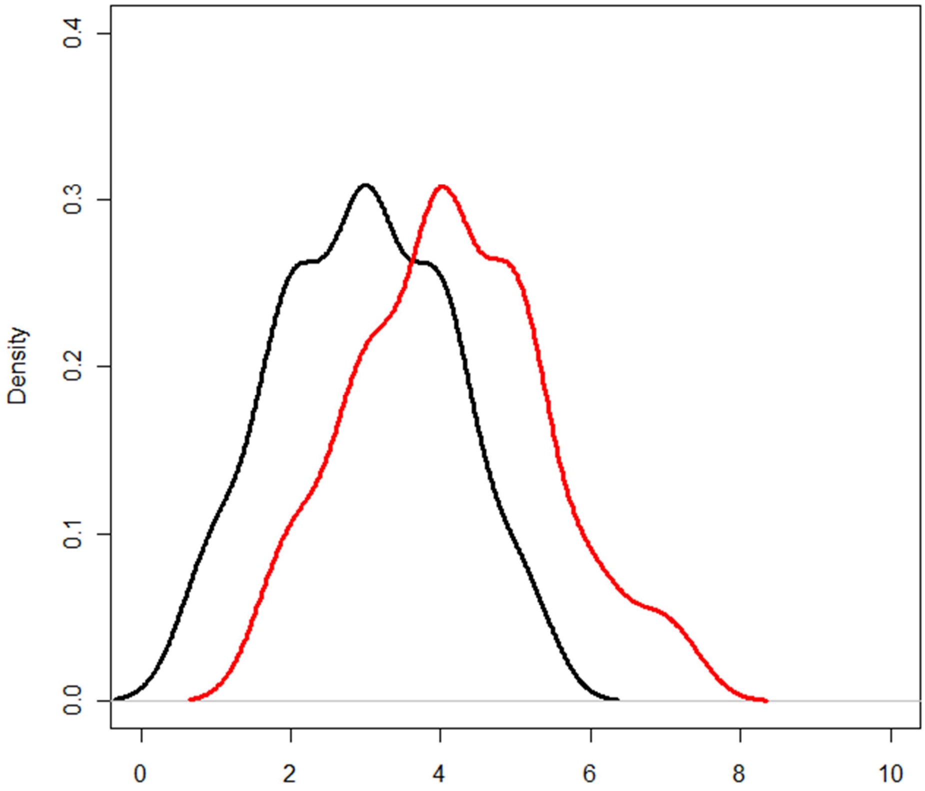


Figure 16 Distribution of the number of stops per route (Pilot 1 in black and Baseline 1 in red).

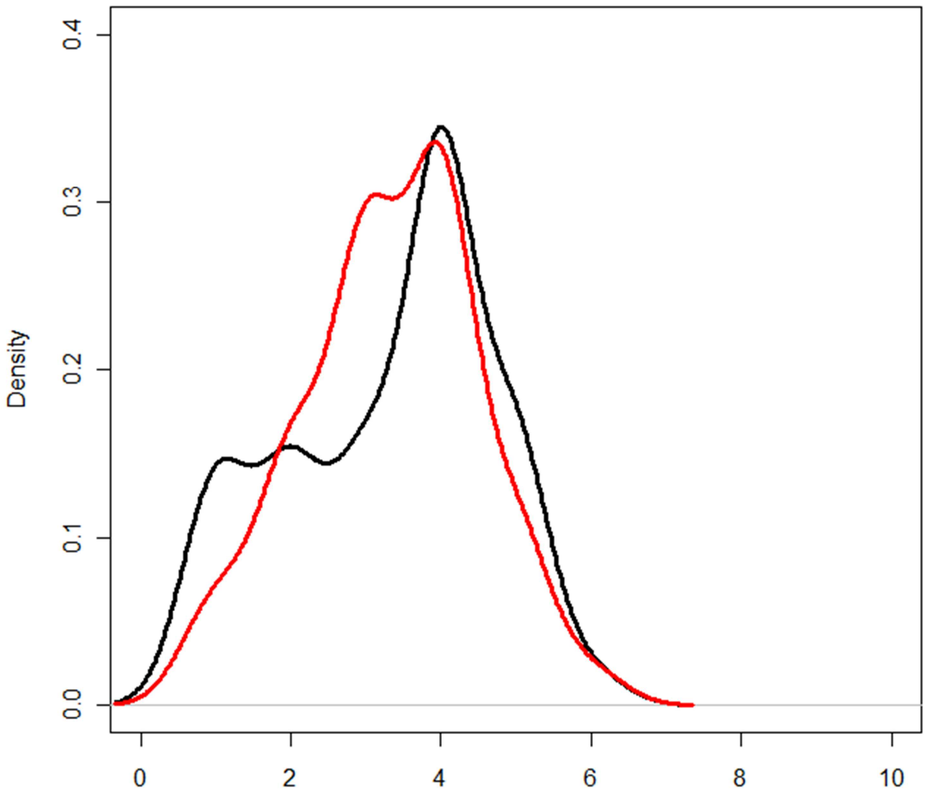


Figure 17 The same as Figure 16 but with Pilot 3 in black and Baseline 2 in red.

Figure 18 and Figure 19 reports the yearly distribution of stops according to each period. The introduction of EEIC has a clear impact on the number of stops (green vs red), in both average and variability. Then, the introduction of a new light in Summer seems to have few impact until September (the second half of the grey graph). The introduction of a control on this light seems to have little impact on the number of stops with respect to the precedent situation (blue vs grey).

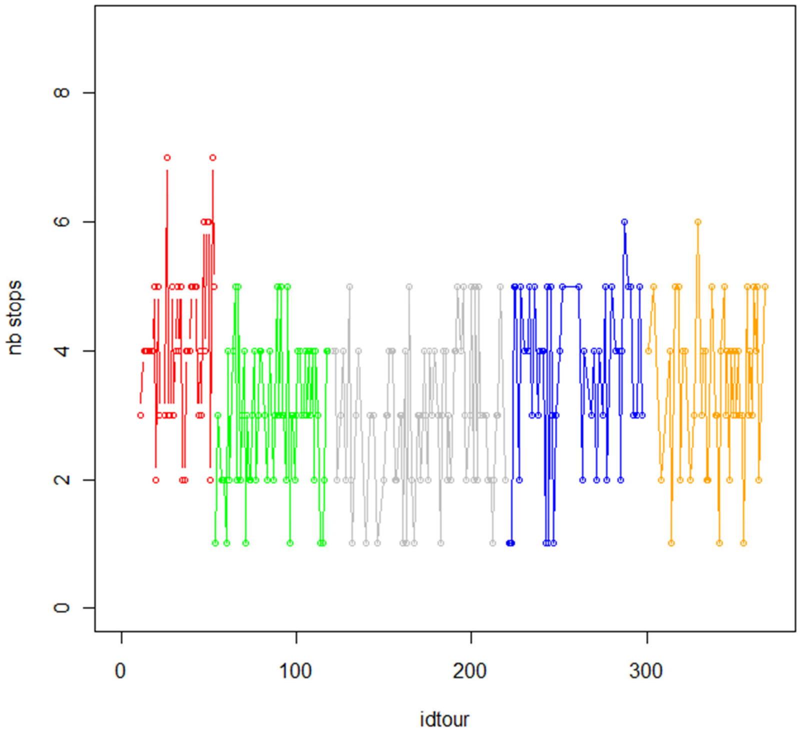


Figure 18 Yearly distribution of the number of stops with the additional traffic light.

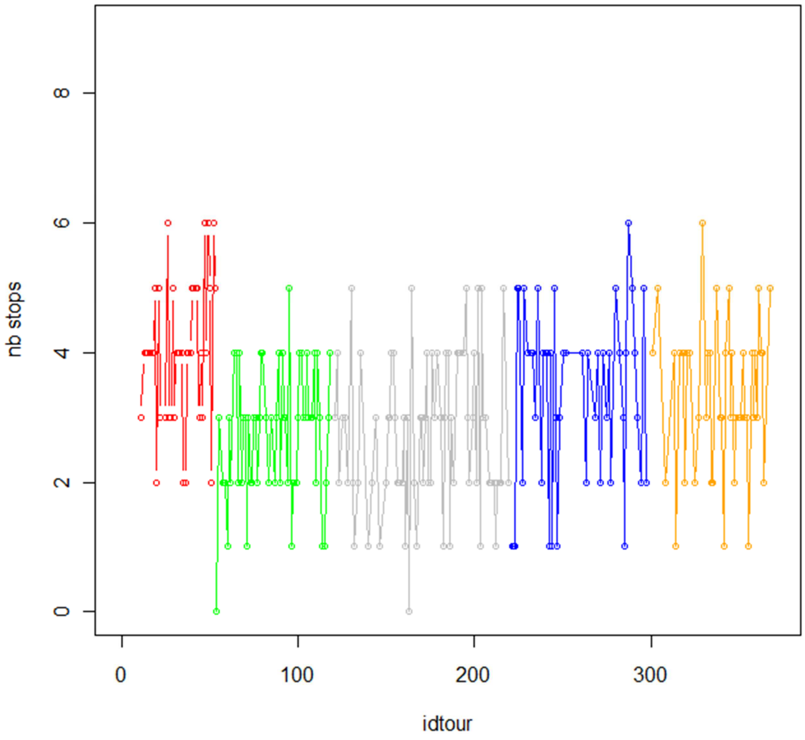


Figure 19 The same as Figure 18 but without the additional traffic light.

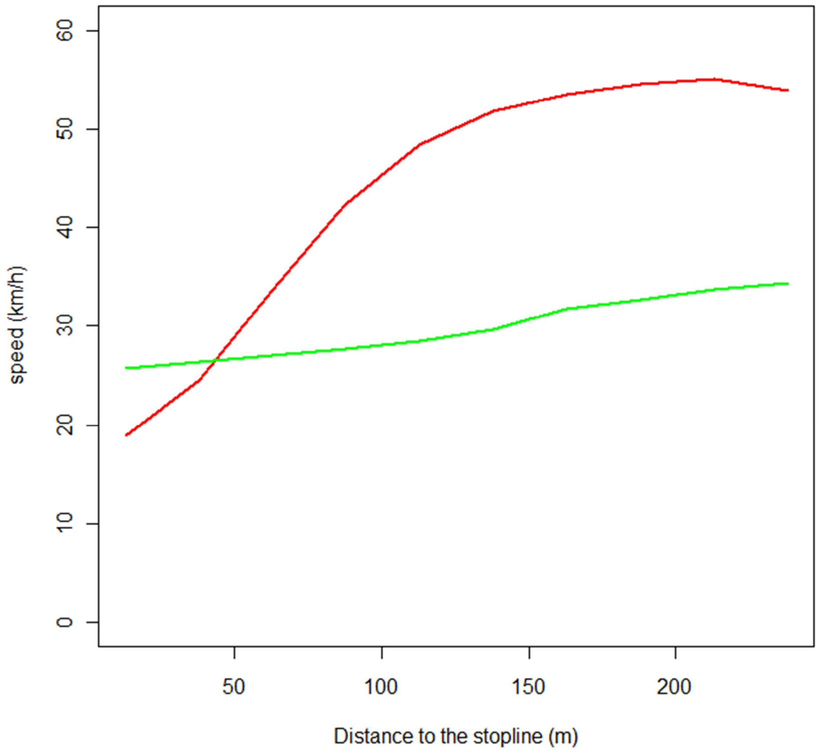


Figure 20 Real speed of the truck (in red) compared with the advised speed (in green).

Figure 20 shows that the truck usually exceeds the speed limit.

Baseline 1 and Pilot 1

	Baseline		Pilot		Fuel consumption			CO2 emissions			NOx emissions			Speed		
Intersection	Nb vehicles	Nb stops	Nb vehicles	Nb stops	Baseline	Pilot	Variation	Baseline	Pilot	Variation	Baseline	Pilot	Variation	Baseline	Pilot	Variation
0 39	39	5	61	15	10,7	11,6	8,4%	294	318	8,2%	1,804	1,964	8,9%	45	40	-11,1%
0 52	39	0	61	0	13,2	14,6	10,6%	361	398	10,2%	2,034	2,25	10,6%	51	45	-11,8%
0 67	39	15	61	23	13,8	13,3	-3,6%	373	362	-2,9%	2,262	2,173	-3,9%	35	38	8,6%
0 68	39	19	61	30	14,2	14,4	1,4%	387	389	0,5%	2,301	2,383	3,6%	37	33	-10,8%
0 6	39	34	61	32	18,4	19,1	3,8%	503	515	2,4%	3,024	2,934	-3,0%	25	32	28,0%
0 27	39	23	61	14	14,7	12,1	-17,7%	400	330	-17,5%	2,414	1,931	-20,0%	32	49	53,1%
0 26	39	20	61	8	16,2	12,2	-24,7%	444	338	-23,9%	2,616	1,944	-25,7%	31	49	58,1%
0 78	39	0	61	1	16	12,6	-21,3%	438	351	-19,9%	2,34	1,993	-14,8%	53	52	-1,9%
0 25	39	24	61	33	16	15,5	-3,1%	436	424	-2,8%	2,599	2,628	1,1%	31	30	-3,2%
0 16	39	27	59	21	9,1	9,4	3,3%	246	252	2,4%	3,203	1,829	-42,9%	12	35	191,7%

Baseline 2 and Pilot 3

	Baseline		Pilot		Fuel consumption			CO2 emissions			NOx emissions			Speed		
Intersection	Nb vehicles	Nb stops	Nb vehicles	Nb stops	Baseline	Pilot	Variation	Baseline	Pilot	Variation	Baseline	Pilot	Variation	Baseline	Pilot	Variation
0 39	45	6	48	12	10,4	10,8	3,8%	282	295	4,6%	1,775	1,914	7,8%	43	37	-14,0%
0 52	45	0	48	1	13,9	13,4	-3,6%	377	365	-3,2%	2,138	2,125	-0,6%	49	45	-8,2%
0 67	45	3	48	16	11,8	13,8	16,9%	318	377	18,6%	1,919	2,32	20,9%	45	33	-26,7%
0 68	45	26	48	24	14	13,8	-1,4%	379	374	-1,3%	2,366	2,323	-1,8%	31	33	6,5%
0 6	45	25	48	23	18	17,5	-2,8%	489	475	-2,9%	2,87	2,794	-2,6%	30	31	3,3%
0 27	45	18	48	25	12,7	12,2	-3,9%	347	332	-4,3%	2,079	2,055	-1,2%	40	38	-5,0%
0 26	45	26	48	16	14,8	11,9	-19,6%	406	322	-20,7%	2,506	2,014	-19,6%	30	39	30,0%
0 78	45	0	48	5	15,2	13,6	-10,5%	414	369	-10,9%	2,293	2,153	-6,1%	49	45	-8,2%
0 25	45	23	48	32	15,5	15,8	1,9%	426	432	1,4%	2,619	2,67	1,9%	28	28	0,0%
0 16	45	30	43	17	11,8	4	-66,1%	314	106	-66,2%	4,849	1,744	-64,0%	7	20	185,7%

Average gains:

Fuel: 10%

CO2: 10%

NOx: 8%

Speed increase: 20%

Another system was tested in Lyon on the Jean Jaurès Avenue. This system consists of a green wave especially designed for trucks. Green waves (of both types: cars or trucks) are almost equally efficient, in the sense that the number of consecutive green lights crossed (two or more), is approximately of 57% in this case.

Wavetype	Min 1 green light	Min 2 green lights	Min 3 green lights	Min 4 green lights
Car	0.9787234	0.57446809	0.12765957	0.0212766
Pilot	0.71710526	0.57236842	0.09868421	0.01973684
Baseline	0.59067358	0.28497409	0.02590674	0

Table 10 Proportion of vehicles crossing at least 1, 2, 3 or 4 green lights.

In comparison to the pilot, the number of consecutive green lights crossed (two, at least) drops to 28% during the baseline period.

The thin difference between the "Cars" green wave and the "Truck" green wave can be explained by the habits taken by truck drivers to adapt their speed to the "cars" green wave, which is a widely used system. This remark does not necessarily mean that the "trucks" green wave is energetically inefficient. Indeed, the pilot green wave incites to have a lower speed, allowing less consumption and emissions.

Wavetype	Min 1 stop	Min 2 stops	Min 3 stops	Min 4 stops
Car	0.74468085	0.0212766	0	0
Pilot	0.68421053	0.05263158	0	0
Baseline	0.87564767	0.31606218	0.02590674	0.01036269

Table 11 Proportion of vehicles stopping to at least 1, 2, 3 or 4 red lights.

Through the analysis of the number of stops, we can see that the "Trucks" system is more efficient concerning red light stops, because vehicles tend to stop lesser than in baseline and in car green wave. This can be explained by the fact that, even if some truck can adapt to car speed, the biggest trucks cannot do such thing. Again, we can see the number of stops dropping from baseline to pilot. Thanks to the green wave system, no truck stops more than 2 times consecutively.

In the next graphs we can see for each type of vehicle the number of green wave passages compared to the total number of measures.

We can observe that the number of green waves taken thanks to the pilot system increases drastically (from figure 14 to 15). The effect on particular types of vehicles is not significant. We can however state that large trucks benefit the most of this system.

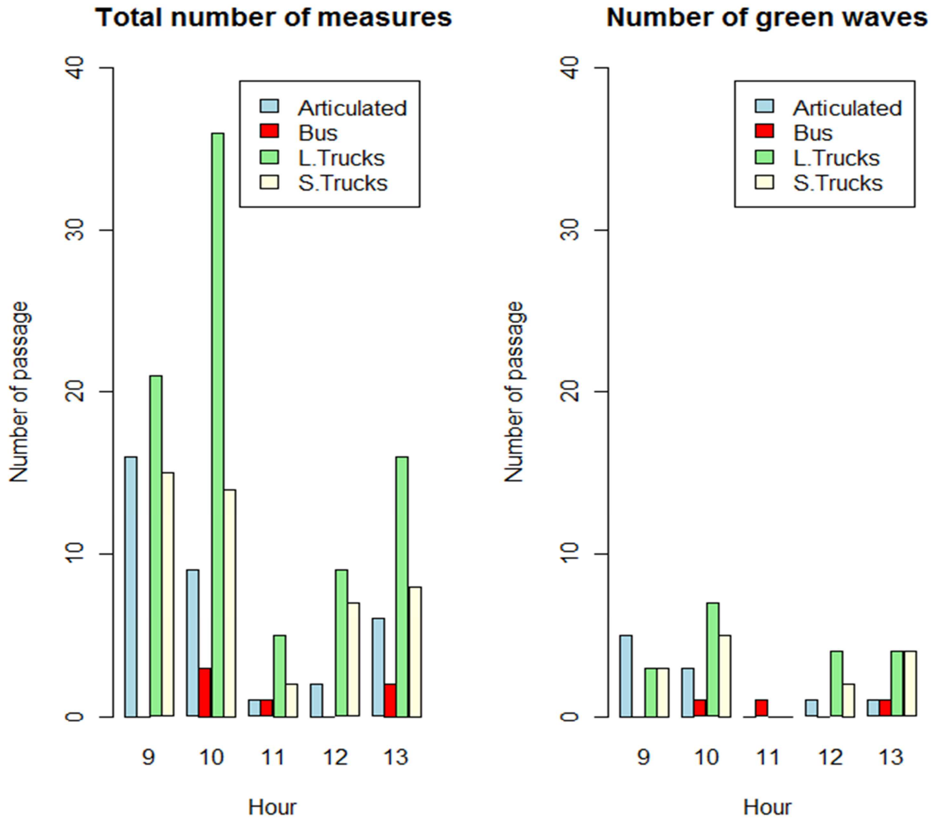


Figure 21 Comparison of the number of measures to the number of green waves taken: no green wave.

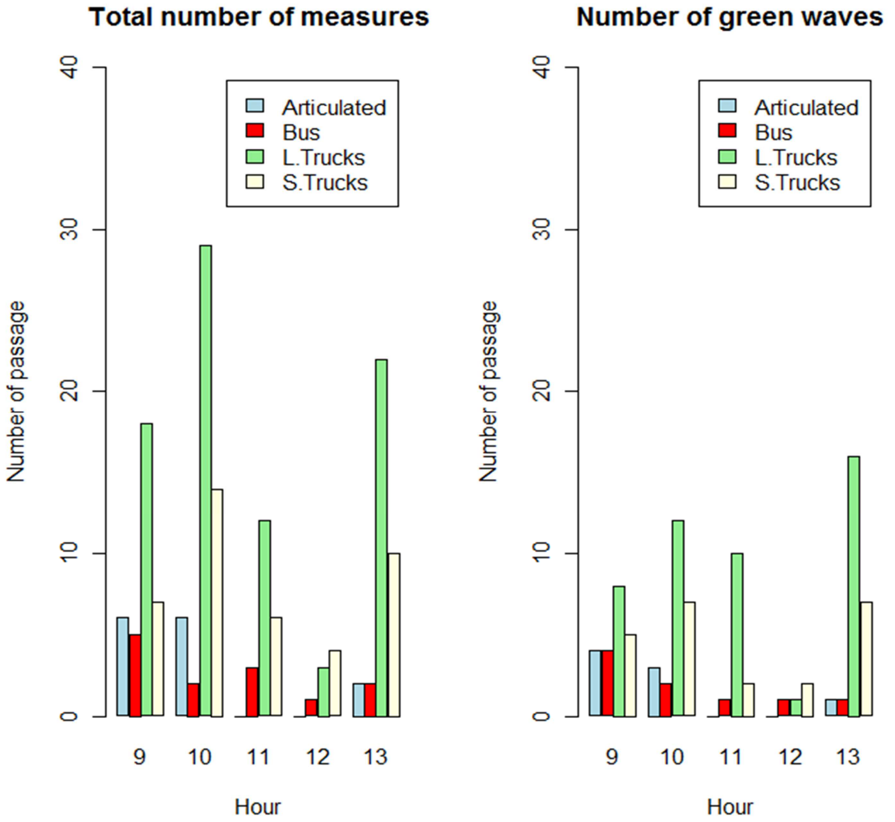


Figure 22 Comparison of the number of measures to the number of green waves taken: truck green wave.

5.1.4. Results in Krakow

The tests on Krakow intersection control were chosen to be carried out on the road 75 near Krakow on eight traffic lights. This road consists of two lanes on the majority of its length, with a few sections with overtaking lanes. The global length of the studied portion is 22km.

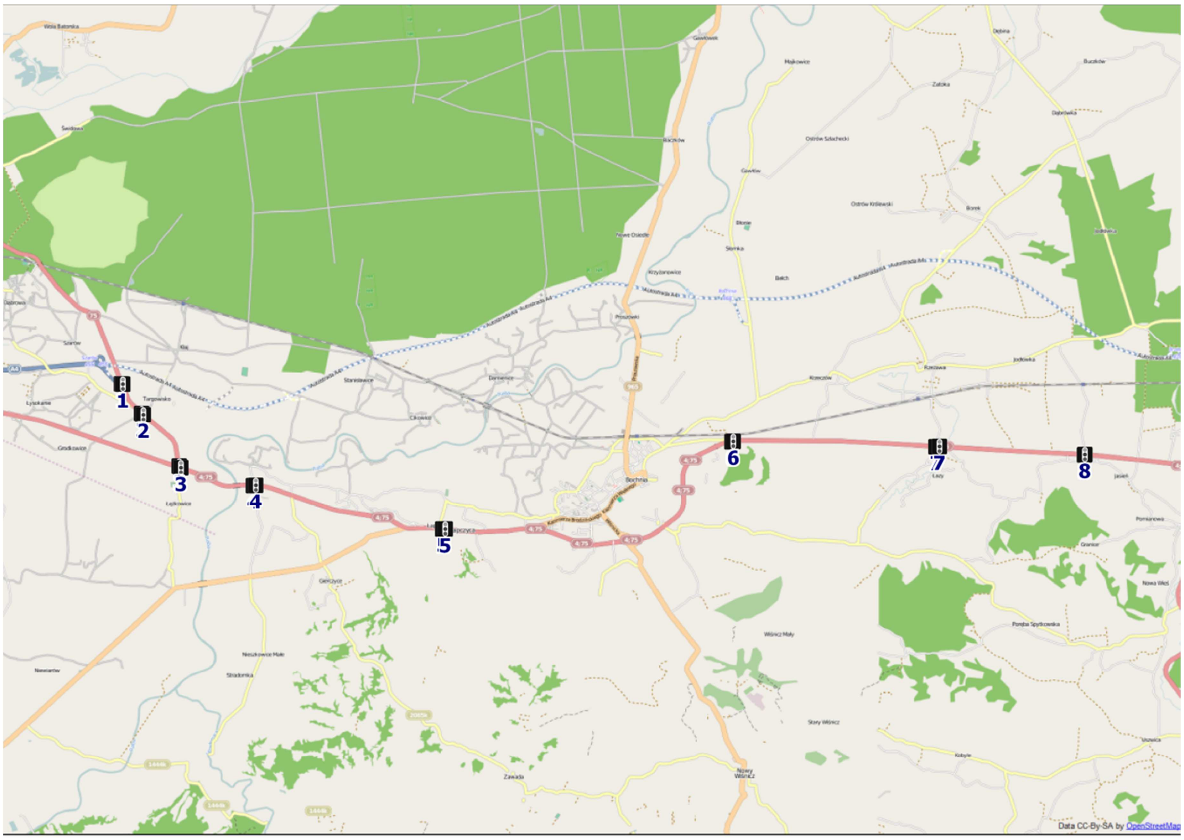


Figure 23: Map of the studied area with the traffic lights and their ID.

The baseline period in Krakow started the 5th April 2011 and ended at the end of February 2012. From here the Pilot started, with data collection on vehicles going to the end of june 2012. Here is a recap table of the data collected

Period	Dates	Firebrigad	Number of delivery rounds	Number of different vehicles
Baseline	From 05/04/2011 to 26/02/2012	0	79	6
Pilot	From 27/02/2012 to 27/06/2012	0	17	2

Table 12: Table detailing the number of rounds and vehicles recorded in baseline and pilot period.

We can see in in the next graph the number of crossings for each period (baseline on the left, pilot on the right).

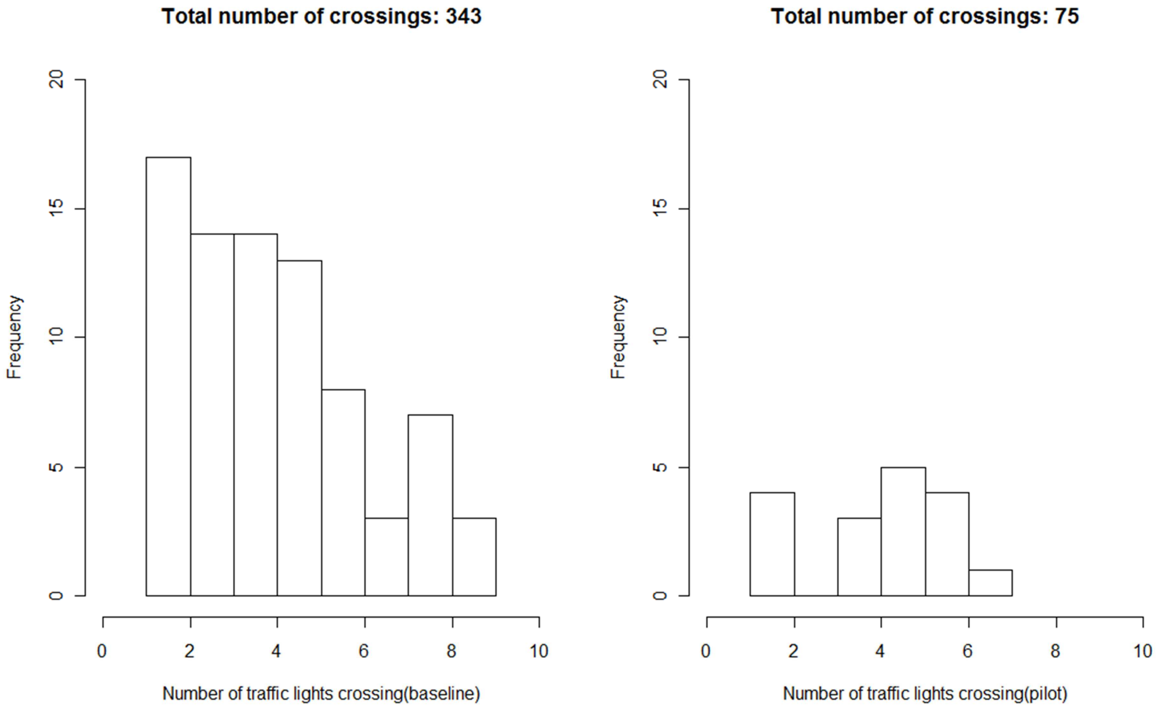


Figure 24: **Graphs representing the frequencies of measures according to the number of traffic lights crossed in a row(baseline on the left, pilot on the right).**

It is important to note that the number of measures during the pilot period is fairly low compared to the baseline. Therefore it is hard to prove the significance of the pilot period concerning the efficiency of the system.

The next graphs measuring the number of stops according to the number of traffic lights crossings indicate the efficiency of the system, with respect to the length of the delivery route. The absolute values show a clear improvement with fewer stops during the pilot period. This is confirmed by a ratio confronting the number of stops and the number of crossings. The high values observed for 7 consecutive traffic lights crossings are high due to the small number of observation (it appears that there is only one measure, in which the truck stopped, see graph 16)

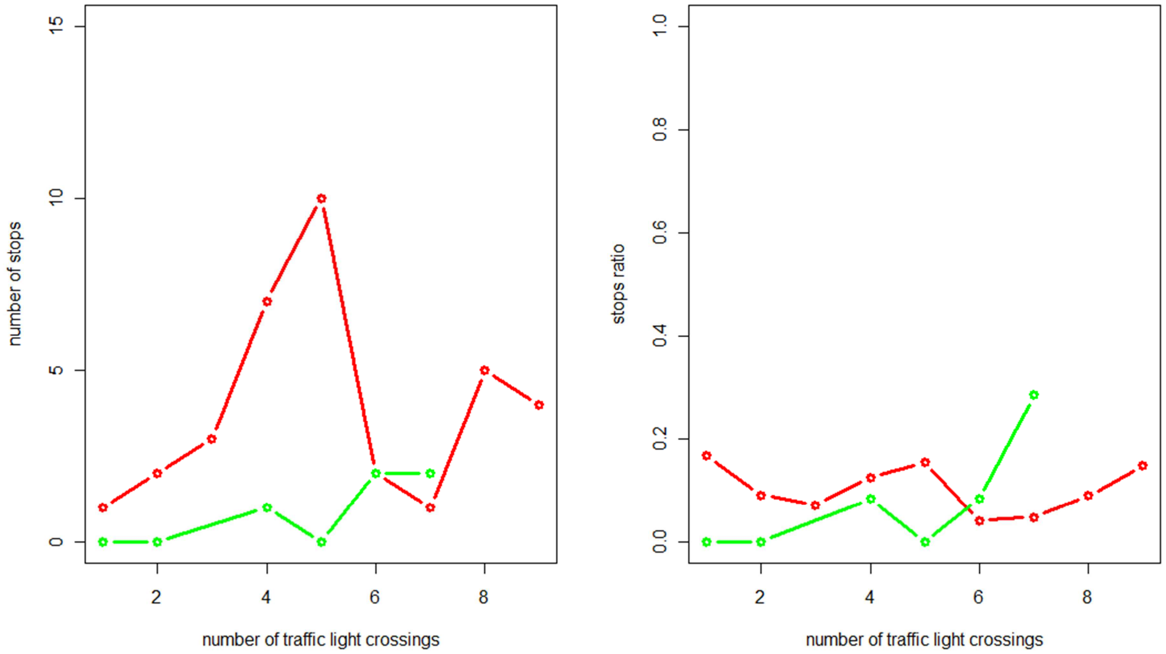


Figure 25: Graphs representing the number of stops in function of the number of traffic lights crossed in a row, right is a ratio of the number of stops and the total number of measures. In red baseline, in green pilot.

The next graph represents the speeds before traffic light crossing during the baseline period (red) and the pilot period (green).

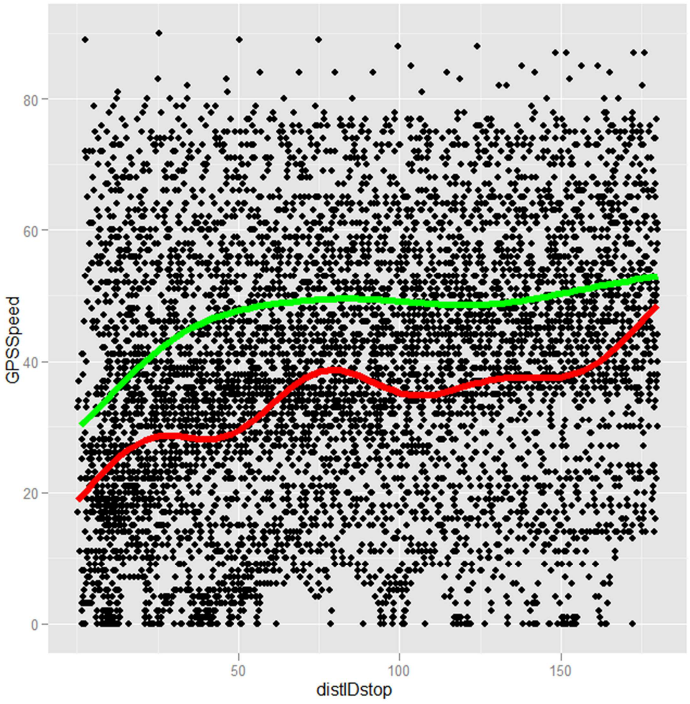


Figure 26: Graph representing the speed (y axis) in function of the distance of the traffic light (x axis). In red the baseline, in green the pilot.

After studying the speed, it is noticeable that the speed profile before traffic light is mainly higher during the pilot period than during the baseline period, favouring shorter durations. Another important point confirming the prior analyses: the speed decreases as the trucks come closer to the traffic lights.

The global analysis on CO2, speed and percentage of stops is globally positive for the pilot results. We can effectively see an improvement in speed and a decrease in the number of stops. However the higher speed does have an effect on the CO2 emissions. The number of measures does not allow the production of reliable indicators for the pilot period. These results seem however rather positive.

Intersection	**Speed avg(B)**	**CO2(g/km) avg(B)**	**Stops (%)(B)**	**Speed avg(P)**	**CO2(g/km) avg(P)**	**Stops (%)(P)**	**Nb of stops indic.**	**Speed indic.**	**CO2 indic.**
1EW	30	803	0%	45	1083	0%	0	++	--
2EW	15	717	6%	51	265	0%	++	++	++
3EN	34	549	11%	53	970	0%	++	++	--
3NE	9	1193	15%	38	904	0%	++	++	++
4EW	49	654	8%	63	990	0%	++	++	--
4WE	37	507	13%	58	590	0%	++	++	--
5WE	46	431	5%	41	571	0%	++	-	--
6WE	49	689	0%	60	657	0%	0	++	--
7EW	33	579	21%	55	779	0%	++	++	--
7WE	30	690	8%	42	585	11%	--	++	++
8WE	42	472	0%	32	540	50%	--	--	--

Table 13: Table comparing the speed (in km/h), CO2 and number of stops at each traffic lights for baseline (B) and pilot(P). Speed and CO2 are calculated in a range of 220m before the traffic light.

The indicator signs ++ indicates an improvement in comparison to the baseline period. On the opposite the signs - - indicates a deterioration. The comparison is for each each significant stopline and direction.

5.2. DSB

5.2.1. Analyses Methodology

The DSB application is tested in Bilbao and Lyon but not exactly in the same way because of the different needs of the local stakeholders in the two cities. In both cases, the DSB system allows an operator or/and his drivers to book a delivery space in advance via internet to load/unload the goods. In addition, in Bilbao the driver, when arrives to parking, can reserve a slot in a specific device in the parking while in Lyon the trucks takes an on board system able to reserve a space or communicate with the back-office system to get more information about the reservations. In this way, it is possible to understand the benefits and costs of the two compared solutions.

The whole FREILOT project is tested with delivery spaces dedicated only to FREILOT partners.

5.2.2. Results in Bilbao

In the pilot site of Bilbao the evaluation is based on three analysis:

- The reservation system database.
- GPS data collected from vehicle stopping at the delivery space.
- Traffic and infraction countings.

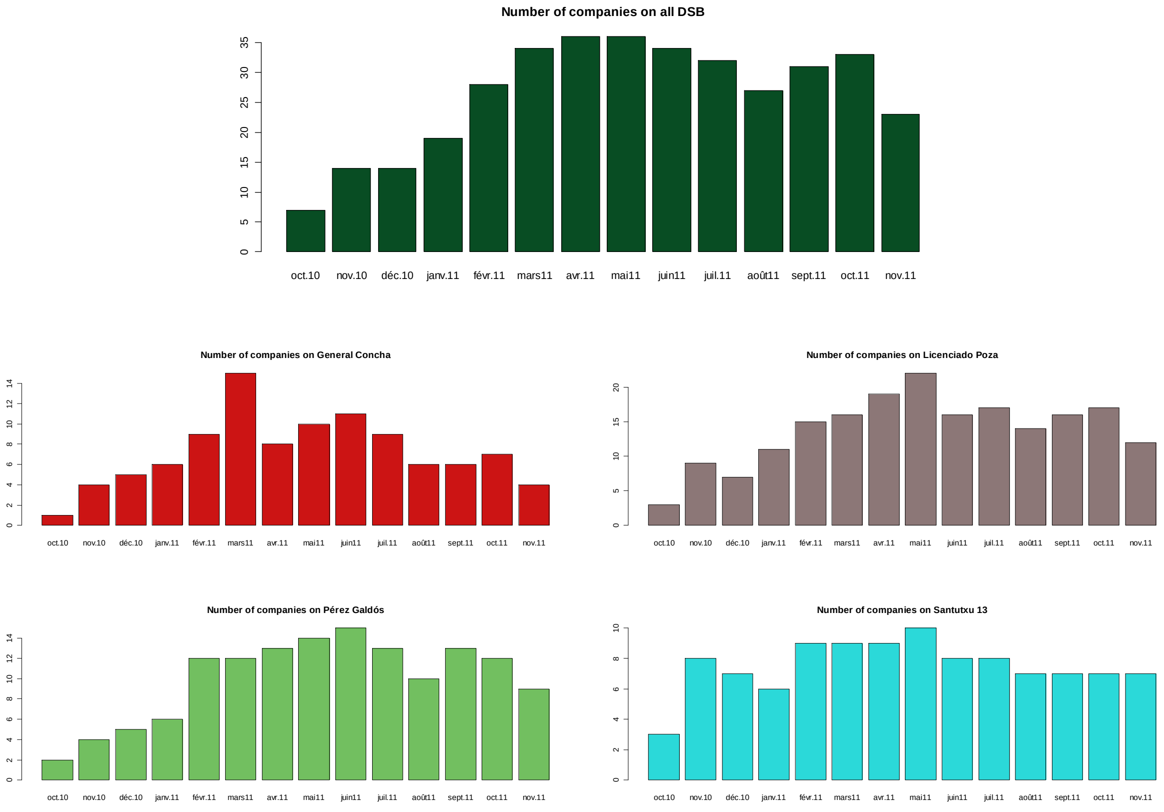
Each experimental design is composed of an experimental period (without any FREILOT service) and a pilot period (with the FREILOT services). During the pilot, the same indicators are analysed with and without the services in order to show the benefits.

The baseline period in Bilbao began the 7th of July 2010 and finished the 28th of October 2010. August data are not considered because in this month the traffic is different. The pilot period began in November 2010 and ended in November 2011. After the pilot’s end, the system remained active and used by the companies until July 2012.

The DSB of Bilbao consists of four pilot spots (Figure 27): Licenciado Poza with three parking zones and Pérez Galdós, General Concha, and Santutxu with two parking zones (D.FL.2.1 Implementation plan).

Figure 27 The four delivery spaces in Bilbao.

5.2.2.1.Data from the reservations system


Number of companies on all DSB

Number of companies on General Concha

Number of companies on Licenciado Poza

Number of companies on Pérez Galdós

Number of companies on Santutxu 13

Figure 28 Distribution of companies along the pilot period.

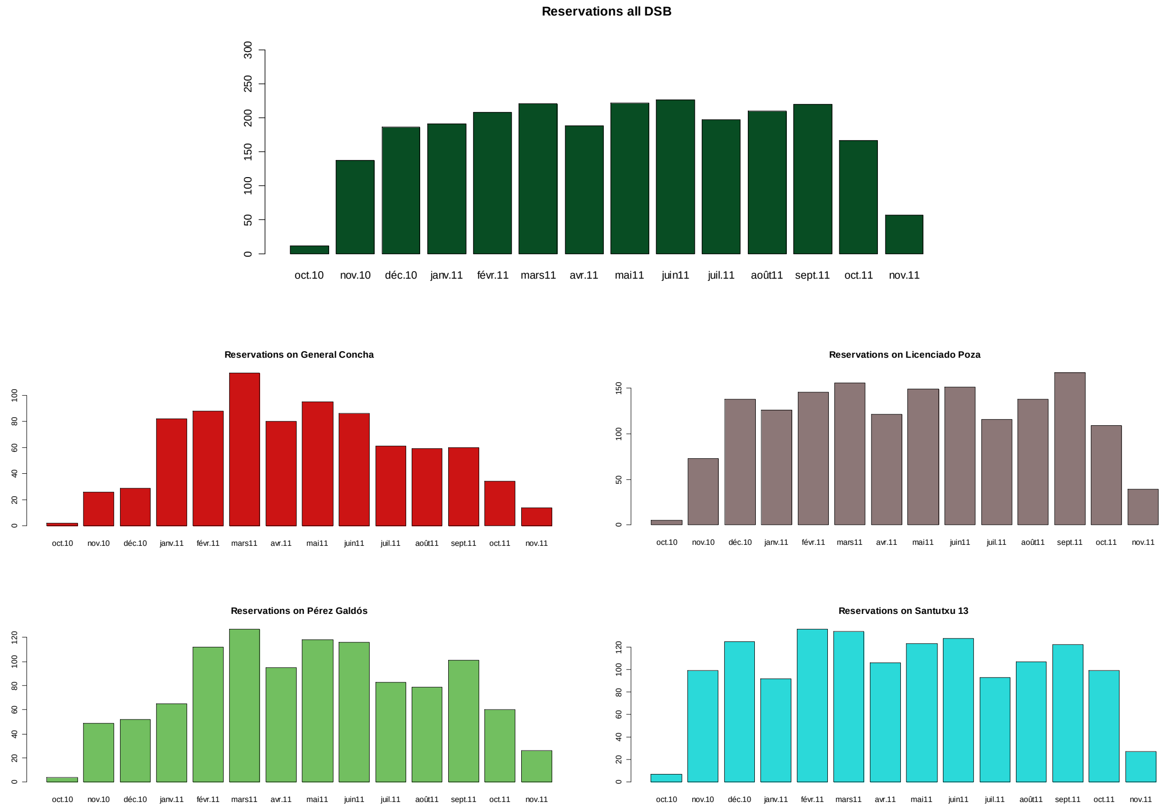


Figure 29 Distribution of reservations along the pilot period.

Figure 28 shows the evolution of the number of companies per month where it can be seen the effect of the entrance of new companies, since 15 companies had access from the beginning but 37 companies were included in January 2011 and 10 in Spring 2011. It is observed that the pilot site with more activity is Licenciado Poza probably because is the one situated in the city center (Figure 27).

Bilbao piloted the UMDM, developed by Gertek, that supports bookings via internet or from parking toll poles so the system not only allows the fleet manager to book in advance an urban delivery space but allows a real-time booking procedure if there is a free slot. The UMDM system also allows fixed bookings for a period of three months allowing in this way a medium time organization to fleet operators.

Figure 29 shows an almost constant number of reservations in all the cases being evidently Licenciado Poza the site with more bookings as it is the site with more trucks. At the beginning, the number of companies is less, so from October 2010 to January 2011 the companies have tested the system and then the number of reservations per company has decreased. It is also observed a small decrease in April (Easter holidays) and August (Summer holidays). During the pilot period 62 trucks had access to the DSB and 49 made at least one reservation.

The procedure sets that the same truck can reserve as many slots as required in one day, however the same truck could never book two consecutive slots. It is also important to note that during the pilot period the loading/unloading timetable is established from Monday to Friday from 8h to 13:30h. In Figure 30 it is observed a different behaviour on each delivery space that probably depends on the transport plans independently of the DSB. Figure 31 shows a few impact of the day of the week on the number of reservations.

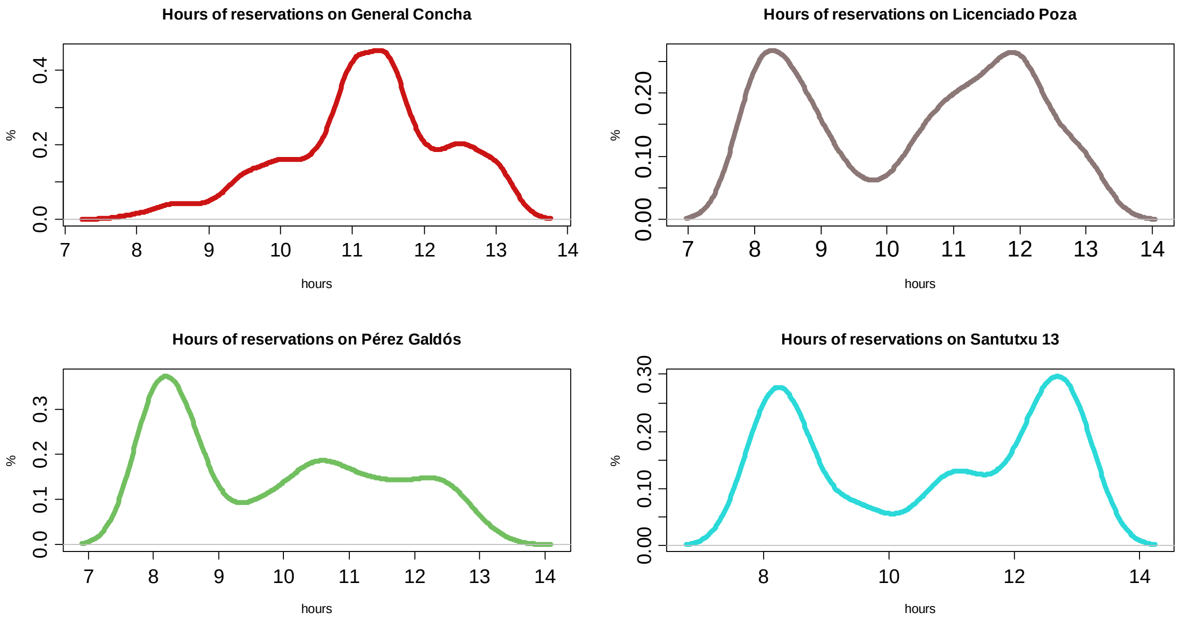


Figure 30 Distribution of reservations during the day period in each pilot site.

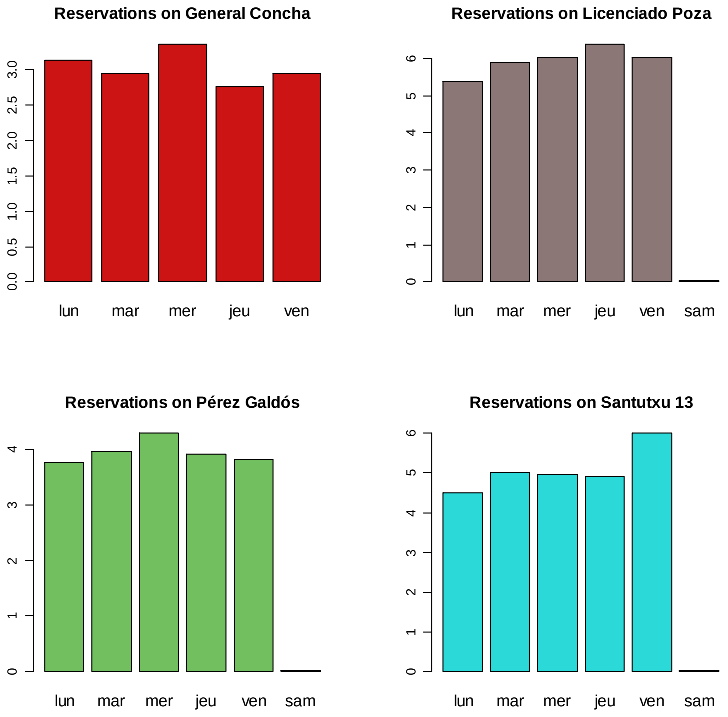


Figure 31 Distribution of reservations per day of week in each site pilot.

In Figure 32 - Figure 36, it is reported for all DSB and for each DSB respectively a) the evolution per week of the number of reservations, b) the reservations effectively parked on the delivery space at the right time and identified in the system, c) the number of companies reserving, and d) the number of infractions. In the latter case, the infractions are considered as unauthorized vehicle parking on the delivery bay.

In all the cases the total number of infractions decreases in the week 69 so it is important to note that the enforcement schemes by local police have started after Easter 2011. It can be concluded that the number of infractions remains still important and can be related to the fact the DSB system is far from being saturated. There is no significant differences among distinct pilot sites (Figure 33 - Figure 36).

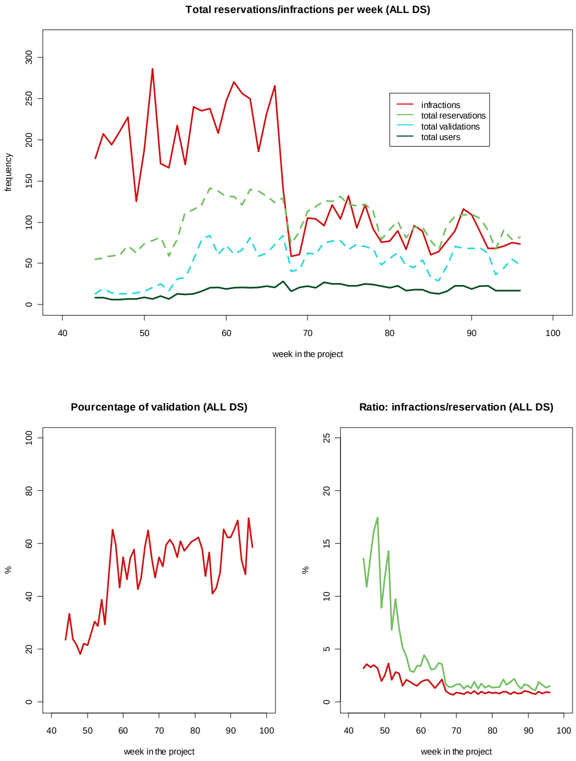


Figure 32 Evolution per week of: the total number of reservations (in green), the total number of validations (in light blue), the total number of users (in black), and the total number of infractions (in red).

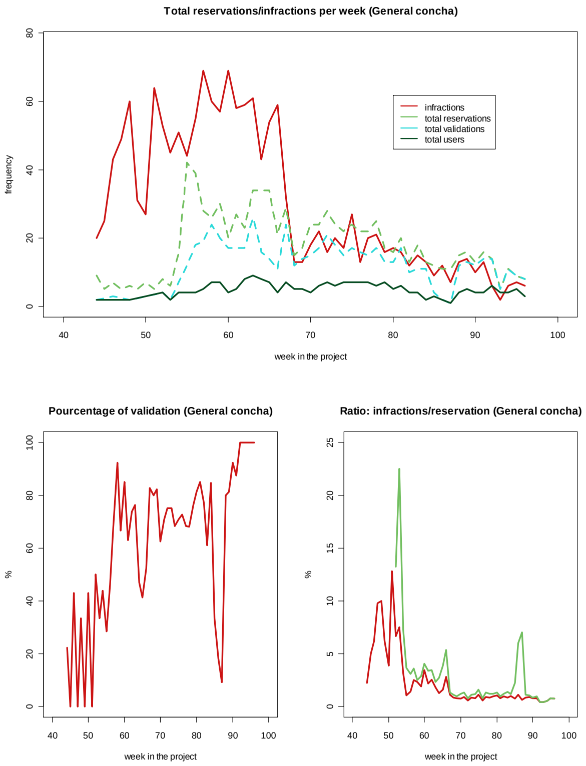


Figure 33 The same as Figure 32 but for the pilot site of General Concha.

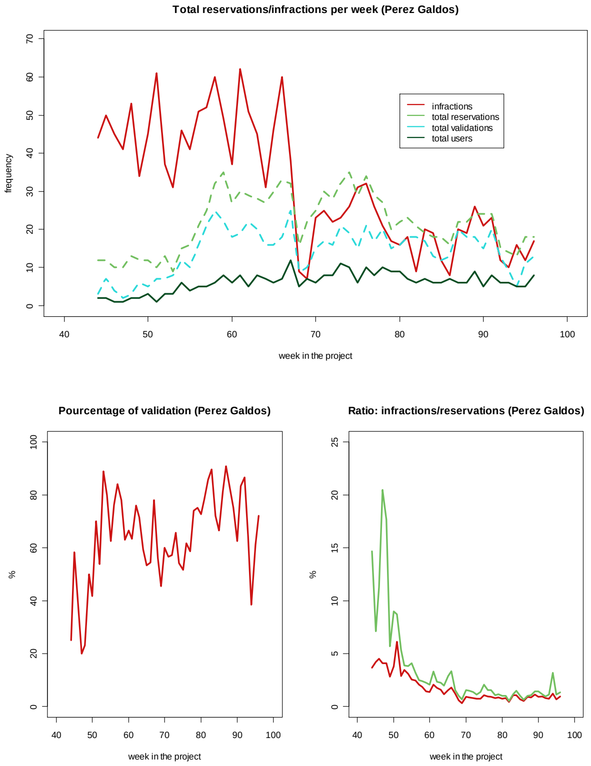


Figure 34 The same as Figure 32 but for the pilot site of Pérez Galdós.

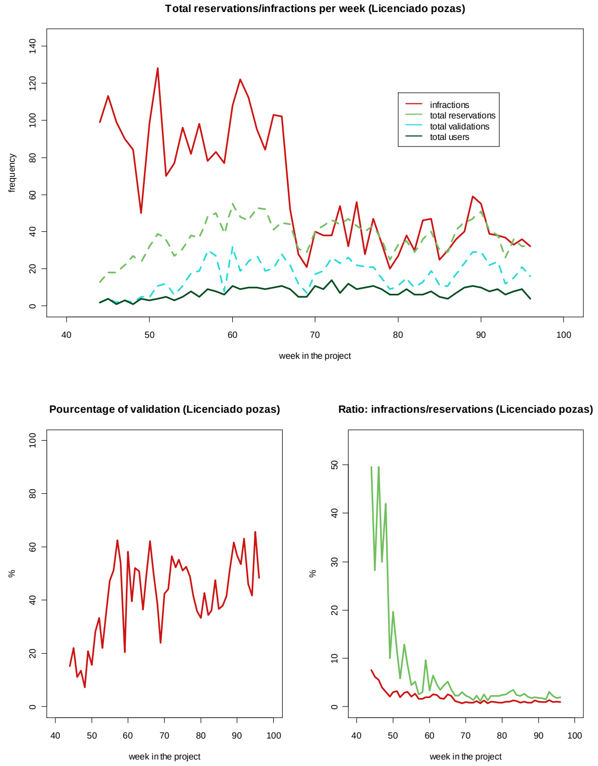


Figure 35 The same as Figure 32 but for the pilot site of Licenciado Poza.

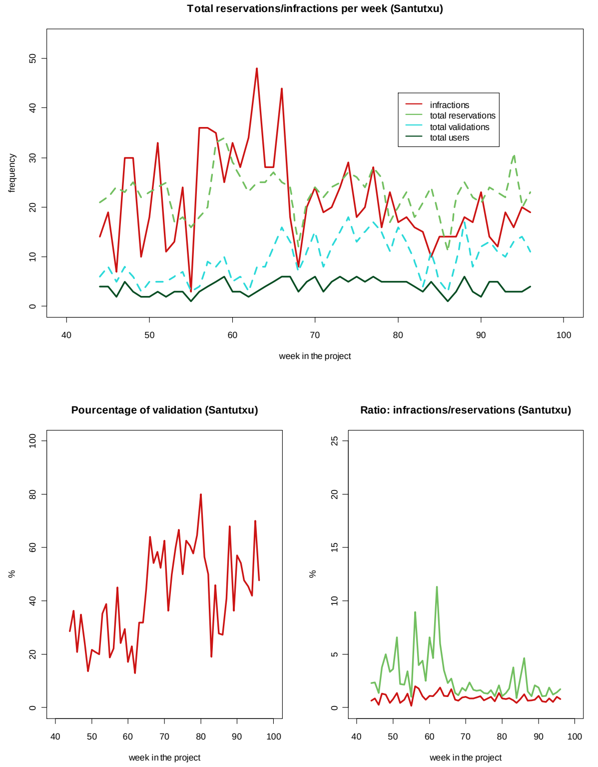


Figure 36 The same as Figure 32 but for the pilot site of Santutxu.

5.2.2.2.GPS data

Each driver logs in to the Blackberry's GPS system before starting the journey and records all GPS data of the journey. This device collects GPS Time, Latitude and GPS Longitude, travelled distance and GPS speed every two seconds. At the end of the journey, files are sent via GPRS to the Bilbao local FTP server. The data recorded with this data logger is processed in order to identify possible bugs, clean the GPS data and track the delivery stops. This information is treated with a data processing algorithm, using the R language (http://www.r-project.org/), that manages the information as follows:

- Distances and speeds are recalculated to check the accuracy of GPS efficiency.
- Some errors are identified in these files:
  - Repetition of a same point – It is produced when the GPS system looses connection with the satellites so the same position is repeated several times. This error can be tracked easily because the calculated distance between two points is equal to zero. It can be corrected by interpolation of GPS positions.
  - Speed or acceleration problems – It can happen that the speed or the acceleration were unrealistic.
- The criterion to consider delivery stops are a speed less than 3 km/h and duration greater than 120 s. It allows excluding stops caused by traffic lights.
- It is used the OpenMapStreet data and it is aggregated streets in three groups: motorway, main road and residential. The affectation is made with the GIS software named PostGIS which looks for each recorded point the corresponding street.
- The last step is to identify the GPS points into the influence areas of each studied delivery space. Therefore, the delivery stops can be identified around the delivery spaces.

Combining this GPS Data with CMEM software fuel consumption is obtained. CMEM model was chosen (D.FL.4.1 Evaluation methodology and plan) because it takes into account accelerations, it is valid for distinct weights of vehicles and it can be easily automated in a computing program. Table 14 shows the official fleet operators taking part in the pilot period classified according the weight of the vehicles. Since fuel consumption and pollutants emissions are proportionally related to this model values such as CO_2, CO, NO_x and HC emissions are also obtained.

Table 14 Official fleet operators.

Group	Companies	Mean of weight including the load	percentage of collected delivery routes
1. Small vehicles	Azkar, Bizkai, DHL, Medrano, MRW and SEUR	3,15 tonnes	15%
2. Medium vehicles	Coca Cola and Patxi	6,95 tonnes	10%
3. Big vehicles	Euskodis, Nanuk, Unialco Rulasan-Eroski and Zubieta-Eroski	18 tonnes	75%

CMEM uses the American model so to calibrate the obtained estimations with the European references is used the ARTEMIS model. In such a way, for each point of the route the instantaneous fuel consumption and CO_2 and NO_X emissions are obtained taking into account the coefficient factor S (Table 15) between the American and the European model. This adjustment is not valid for other pollutants emissions.

	Small vehicles	Medium vehicles	Big vehicles
S	0.4	0.41	0.47

Table 15 Factors of multiplication to pass from CMEM to ARTEMIS.

1693 GPS files were loaded and 1601 are considered valid routes. 1248 routes have at least one delivery stop around the studied delivery spaces. 625 of them (Table 17) were selected because the truck stops at a delivery space during the possible hours of reservations (between 8h and 13:30h).

Group	Travelled distance	Route duration	Average number of deliveries
Small vehicles	46 km	4,9 h	21 (max = 44)
Medium vehicles	62 km	6,9 h	26 (max = 44)
Big vehicles	73 km	3,9 h	11 (max = 22)
All	68 km	4,3 h	14

Table 16 Characteristics of delivery routes.

Pilot site	Number of baseline stops	Number of pilot stops
General Concha	9	46
Pérez Galdós	30	122
Licenciado Poza	31	102
Santutxu	40	208

Table 17 Recorded stops per delivery space.

5.2.2.3.Counting in the street

Automatic traffic counting sensors are installed at streets near the intersections to estimate the traffic intensity in each road. Not all the streets are equipped with sensors but it is possible to estimate the traffic flow taking into account the adjacent equipped streets (D.FL.4.1 Evaluation methodology and plan).

It is assumed that the booking of the delivery space allows the driver not to look for a place in order to deliver the goods. Therefore, the distance and the time between the arrival into the influence area and the real stop are lower when the system works. In addition, fuel consumptions and gas emissions have to be also lower. The situations when the trucks arrive at the proximity of the delivery space can be summarized in three situations:

- The ideal situation: the driver finds a free space and does not look for one.
- The bad situation: the driver does not find a free space and must wait or look for one before the delivery. He may then get around the buildings block in order to find a place. Indeed, distances and times increase and there are more consumptions and emissions.
- The illegal situation: the driver does not find a free space and chooses an illegal space or

double parking. There are no impacts on distances however there can be more congestion according to traffic. With GPS data, it is impossible to separate this situation to the ideal one.

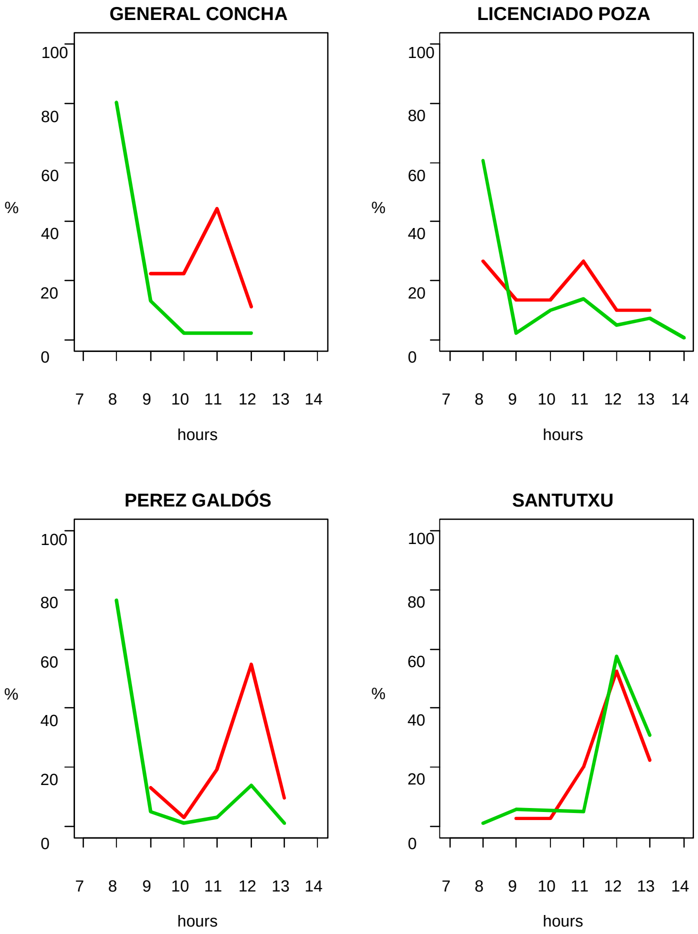


Figure 37 Hours of deliveries (baseline in red and pilot in green).

Figure 37 reports the time distribution of deliveries near the delivery bays. There are big differences between the baseline and the pilot in General Concha and Pérez Galdós. In both cases, the peak of deliveries moves from the late morning (11h/12h) to 8h/9h. In Pérez Galdós, it is observed that the pilot delivery peak corresponds to that of reservations (Figure 30) so the changes could be related to the usage of the DSB system.

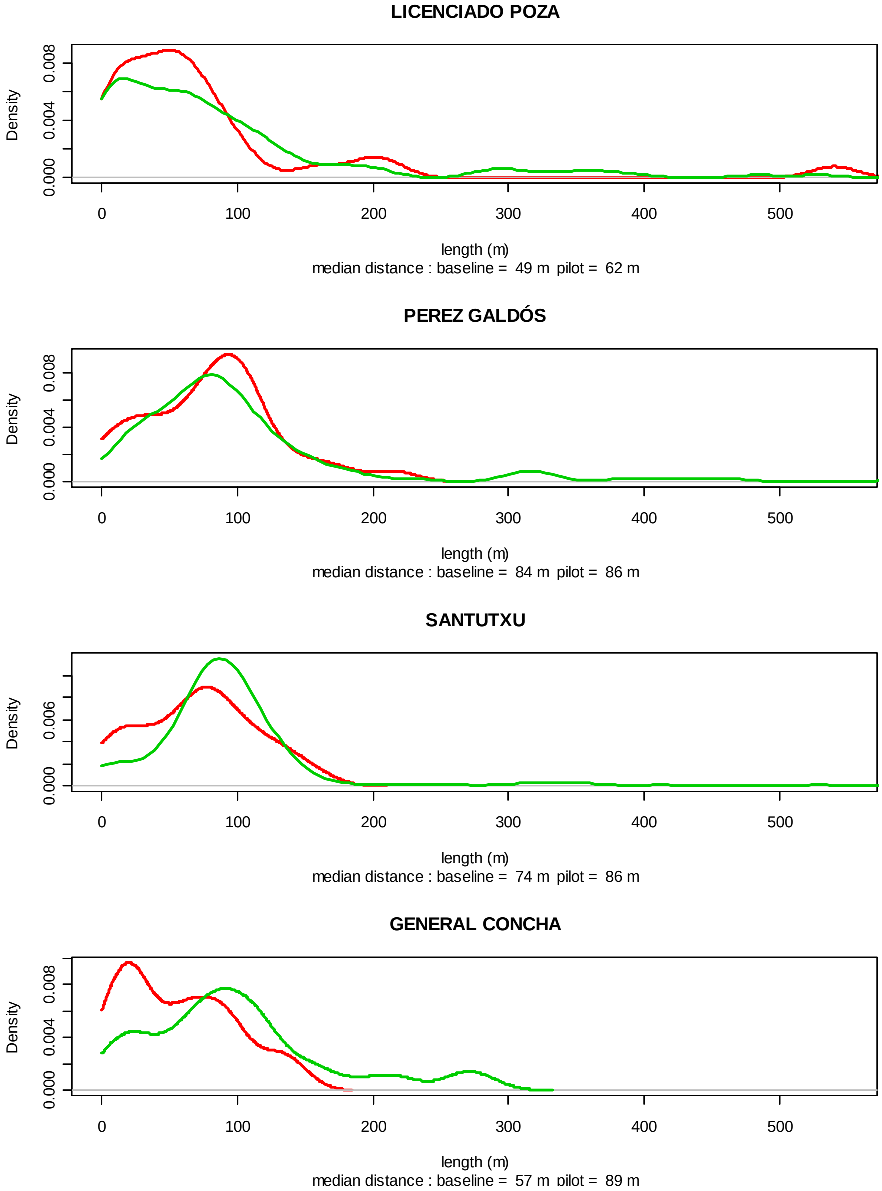


Figure 38 Distribution of the distances before parking (baseline in red and pilot in green).

Table 18 Quartile distances for each site in each period.

Delivery spaces	**Period**	**Q1**	**Q2**	**Q3**	**Q3 - Q1**
Pérez Galdós	baseline	43	84	104	61
Pérez Galdós	pilot	59	86	131	72
Santutxu	baseline	37	74	100	63
Santutxu	pilot	68	86	105	37
General Concha	baseline	22	57	88	66
General Concha	pilot	56	89	119	64
Licenciado Poza	baseline	23	49	82	59

Licenciado Poza	pilot	22	62	120	99

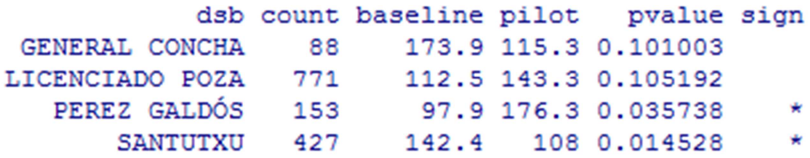
The delivery space is located at 70m from the limits of the influence area. If the distance is above 140m, it is considered that the driver makes a move to be well-parked (a U-turn or a bypass). In the baseline period the driver choose easily free spaces along the road and during the pilot period he uses the reserved slots for the DSB system. Moreover, during the baseline period there are very few situations when the driver must be a manoeuvre to be well-parked. However, some of these situations exists during the pilot period due certainly to a extraordinary traffic.

The considered distances in Figure 38 are the length between the first point into the influence area and the first point of the delivery stop between 8h and 13:30h.

The distribution of the distance travelled to park presents some differences between baseline and pilot and more precisely each delivery bay has a specific behaviour. From now on, General Concha data set is not considered in the analysis because the number of countings is not significant (Figure 39).

Table 18 reports for each DSB and period the quartiles Q1, Q2 and Q3 as well as the inter-quartile distance (Q3-Q1). It is observed that the median (Q2) is slightly higher in the pilot period than in the baseline period for all the pilot sites and only for Santutxu the interquartile distance (Q3-Q1) decreases.

Figure 39 is a results screen from R software that shows that in Licenciado Poza and Pérez Galdos the average of distances during the baseline period is lower than the one of the pilot period (that are upper 140m) but only Pérez Galdós has a p-value with a positive significance. In Santutxu the average of distances is higher in the baseline with a positive significance possibly because the system added a new delivery space, keeping the existing one for deliveries not using the system, but increasing the delivery parking capacity. This is the only transformation of an existing delivery bay into a DSB system.



```
               dsb count baseline pilot   pvalue sign
   GENERAL CONCHA    88    173.9 115.3 0.101003
LICENCIADO POZA   771    112.5 143.3 0.105192
     PEREZ GALDÓS   153     97.9 176.3 0.035738    *
         SANTUTXU   427    142.4   108 0.014528    *
```

Figure 39 p-value in the pilot period for each pilot site.

In order to produce a more detailed analysis the distance distribution per category of vehicle is carried out. Table 19 shows that although the median is slighty higher in the pilot period the interquartile distance decreases in all pilos sites, except Licenciado Poza. This reflects a decrease of the variability in the travelled distance to park Table 20 and Figure 42 show better gains for pilot period in medium vehicles. Figure 41 and Figure 42 show that only Pérez Galdós breaks the trend and for medium vehicles and big vehicles Q2 is lower in the pilot period but on the contrary the average of distances increases. Except for Santutxu, the DSB seems to have a negative impact on distances for heavy vehicles, which is directly related to the characteristics of the vehicles. Indeed, these vehicles are long and heavy and have more difficulties to travel and park in city centres.

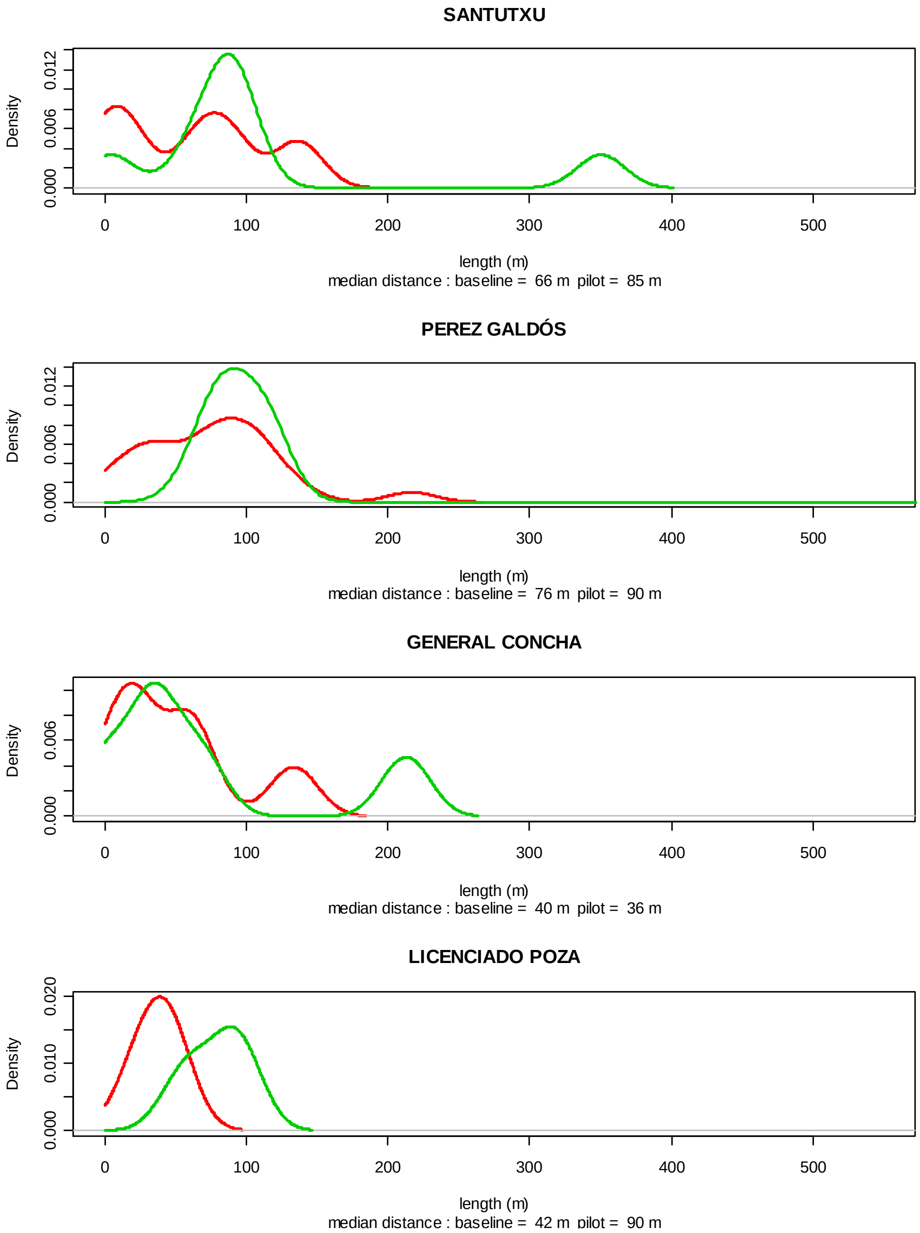
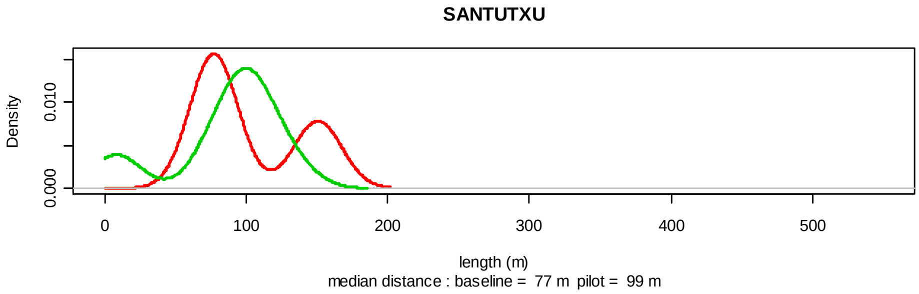
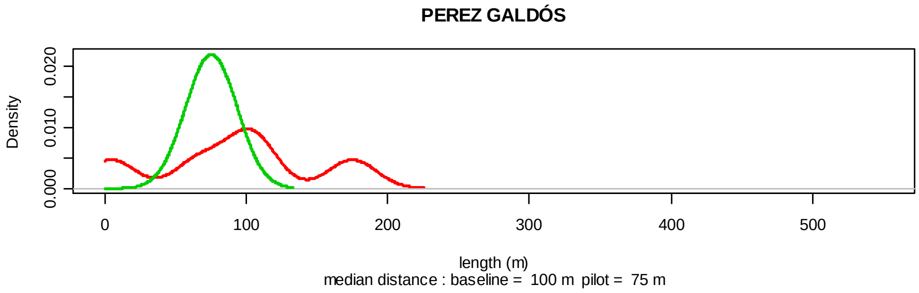


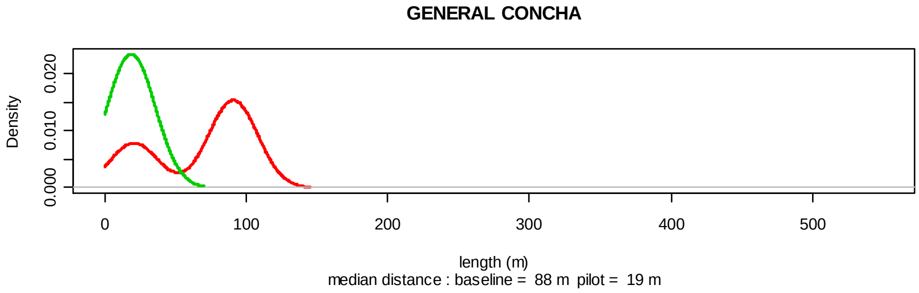
Figure 40 The same as Figure 38 but for small vehicles.

Table 19 The same as Table 18 but for small vehicles.

Delivery spaces	Period	Q1	Q2	Q3	Q3 - Q1
Pérez Galdós	baseline	41	76	102	61
Pérez Galdós	pilot	82	90	113	32
Santutxu	baseline	17	66	88	71
Santutxu	pilot	72	85	95	23
General Concha	baseline	22	40	62	40
General Concha	pilot	34	36	68	35
Licenciado Poza	baseline	33	42	44	11
Licenciado Poza	pilot	61	90	92	32







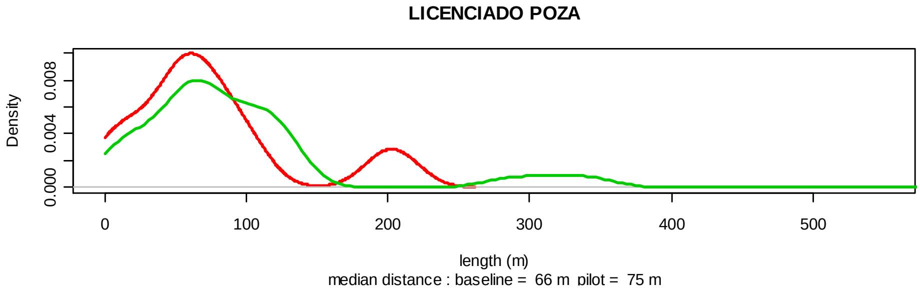


Figure 41 The same as Figure 38 but for medium vehicles.

Delivery spaces	Period	Q1	Q2	Q3	Q3 - Q1
Pérez Galdós	baseline	67	100	106	40
Pérez Galdós	pilot	72	75	78	6
Santutxu	baseline	77	77	114	37
Santutxu	pilot	81	99	106	25
General Concha	baseline	54	88	91	37
General Concha	pilot	19	19	19	0
Licenciado Poza	baseline	44	66	89	45
Licenciado Poza	pilot	54	75	117	62

Table 20 The same as Table 18 but for medium vehicles.

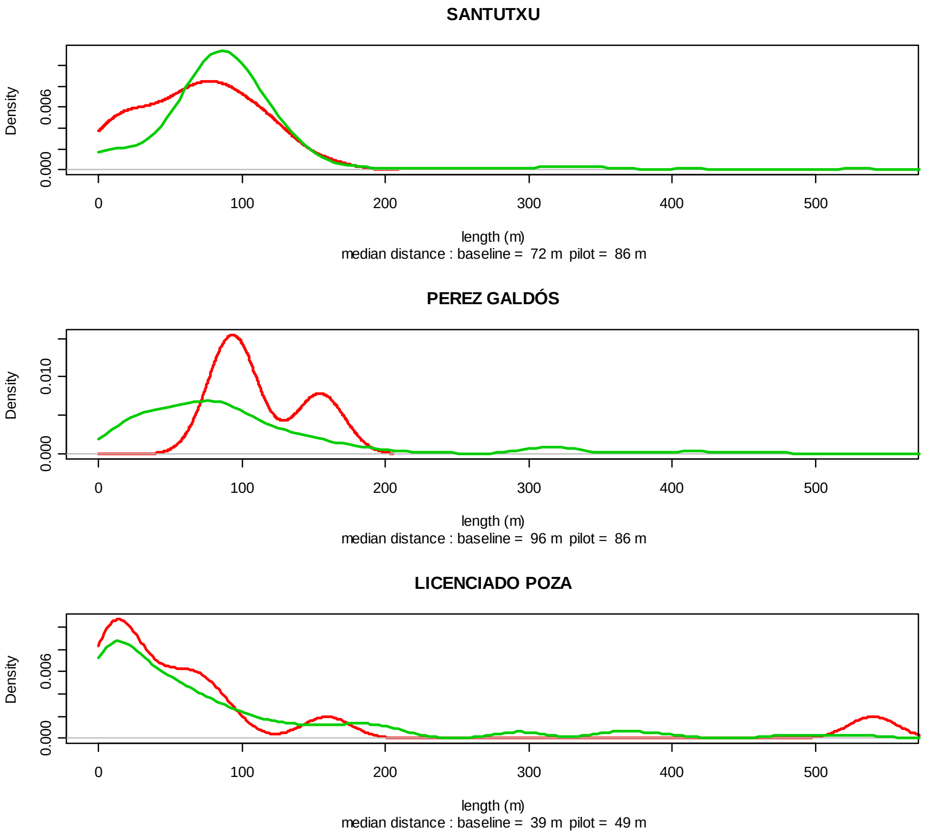
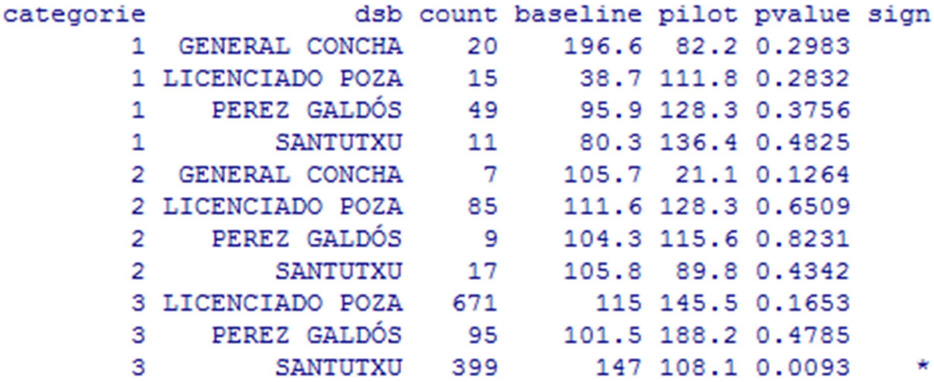


Figure 42 The same as Figure 38 but for medium vehicles.

Delivery spaces	**Period**	**Q1**	**Q2**	**Q3**	**Q3 - Q1**
Pérez Galdós	baseline	93	96	125	32
Pérez Galdós	pilot	51	86	145	93
Santutxu	baseline	37	72	100	63
Santutxu	pilot	68	86	105	37
Licenciado Poza	baseline	12	39	72	60
Licenciado Poza	pilot	14	49	129	115

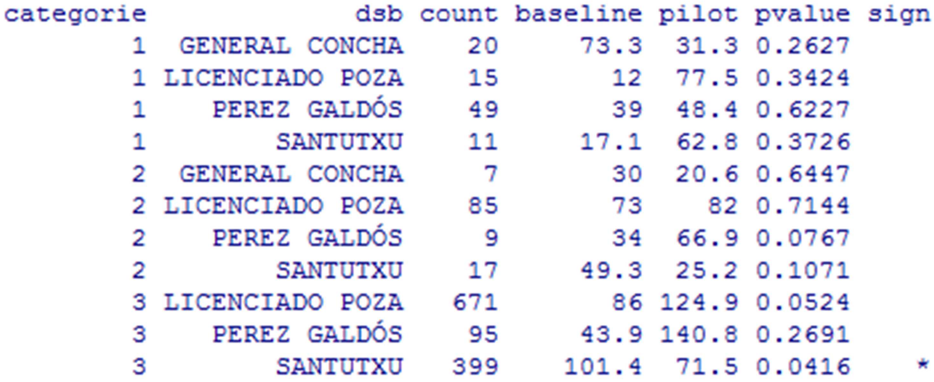
Table 21 The same as Table 18 but for big vehicles.



```
categorie             dsb count baseline pilot pvalue sign
        1  GENERAL CONCHA    20    196.6  82.2 0.2983
        1 LICENCIADO POZA    15     38.7 111.8 0.2832
        1     PEREZ GALDÓS    49     95.9 128.3 0.3756
        1         SANTUTXU    11     80.3 136.4 0.4825
        2  GENERAL CONCHA     7    105.7  21.1 0.1264
        2 LICENCIADO POZA    85    111.6 128.3 0.6509
        2     PEREZ GALDÓS     9    104.3 115.6 0.8231
        2         SANTUTXU    17    105.8  89.8 0.4342
        3 LICENCIADO POZA   671      115 145.5 0.1653
        3     PEREZ GALDÓS    95    101.5 188.2 0.4785
        3         SANTUTXU   399      147 108.1 0.0093    *
```

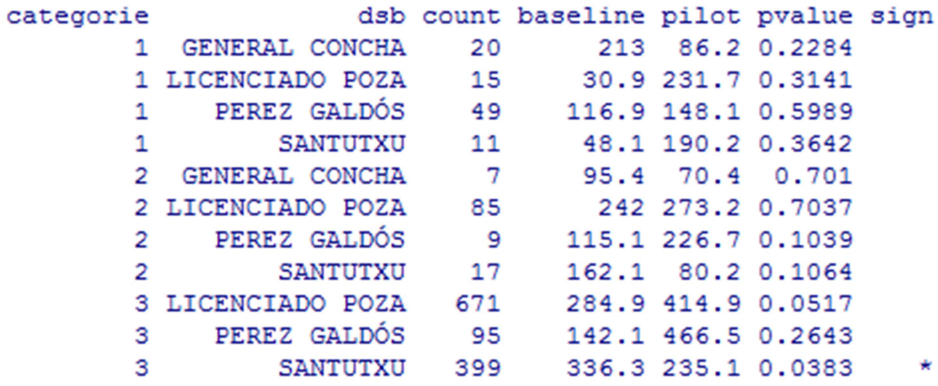
Figure 43 The same as Figure 39 but for each category of vehicle.

Figure 44 - Figure 46 show the emissions when trucks arrive into the influence are until parking.



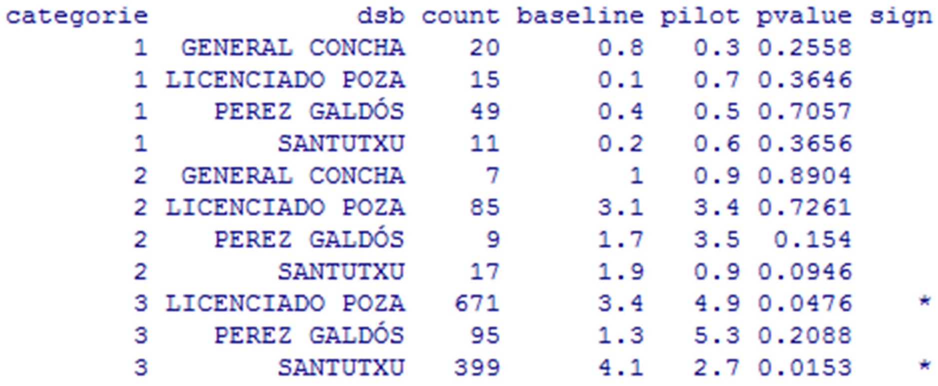
```
categorie             dsb count baseline pilot pvalue sign
        1  GENERAL CONCHA    20     73.3  31.3 0.2627
        1 LICENCIADO POZA    15       12  77.5 0.3424
        1     PEREZ GALDÓS    49       39  48.4 0.6227
        1         SANTUTXU    11     17.1  62.8 0.3726
        2  GENERAL CONCHA     7       30  20.6 0.6447
        2 LICENCIADO POZA    85       73    82 0.7144
        2     PEREZ GALDÓS     9       34  66.9 0.0767
        2         SANTUTXU    17     49.3  25.2 0.1071
        3 LICENCIADO POZA   671       86 124.9 0.0524
        3     PEREZ GALDÓS    95     43.9 140.8 0.2691
        3         SANTUTXU   399    101.4  71.5 0.0416    *
```

Figure 44 Fuel consumption in g.



```
categorie              dsb count baseline pilot pvalue sign
        1   GENERAL CONCHA    20      213  86.2 0.2284
        1 LICENCIADO POZA     15     30.9 231.7 0.3141
        1     PEREZ GALDÓS    49    116.9 148.1 0.5989
        1         SANTUTXU    11     48.1 190.2 0.3642
        2   GENERAL CONCHA     7     95.4  70.4  0.701
        2 LICENCIADO POZA     85      242 273.2 0.7037
        2     PEREZ GALDÓS     9    115.1 226.7 0.1039
        2         SANTUTXU    17    162.1  80.2 0.1064
        3 LICENCIADO POZA    671    284.9 414.9 0.0517
        3     PEREZ GALDÓS    95    142.1 466.5 0.2643
        3         SANTUTXU   399    336.3 235.1 0.0383    *
```

Figure 45 *CO_2* emissions in g.



```
categorie              dsb count baseline pilot pvalue sign
        1   GENERAL CONCHA    20      0.8   0.3 0.2558
        1 LICENCIADO POZA     15      0.1   0.7 0.3646
        1     PEREZ GALDÓS    49      0.4   0.5 0.7057
        1         SANTUTXU    11      0.2   0.6 0.3656
        2   GENERAL CONCHA     7        1   0.9 0.8904
        2 LICENCIADO POZA     85      3.1   3.4 0.7261
        2     PEREZ GALDÓS     9      1.7   3.5  0.154
        2         SANTUTXU    17      1.9   0.9 0.0946
        3 LICENCIADO POZA    671      3.4   4.9 0.0476    *
        3     PEREZ GALDÓS    95      1.3   5.3 0.2088
        3         SANTUTXU   399      4.1   2.7 0.0153    *
```

Figure 46 *NO_x* emissionsin g.

Remains to evaluate the impact of the DSB on traffic. To do this, an infraction counting campaing has been carried out. The baseline took place in 2010 (june-september) and the pilot in 2011 (january-june).

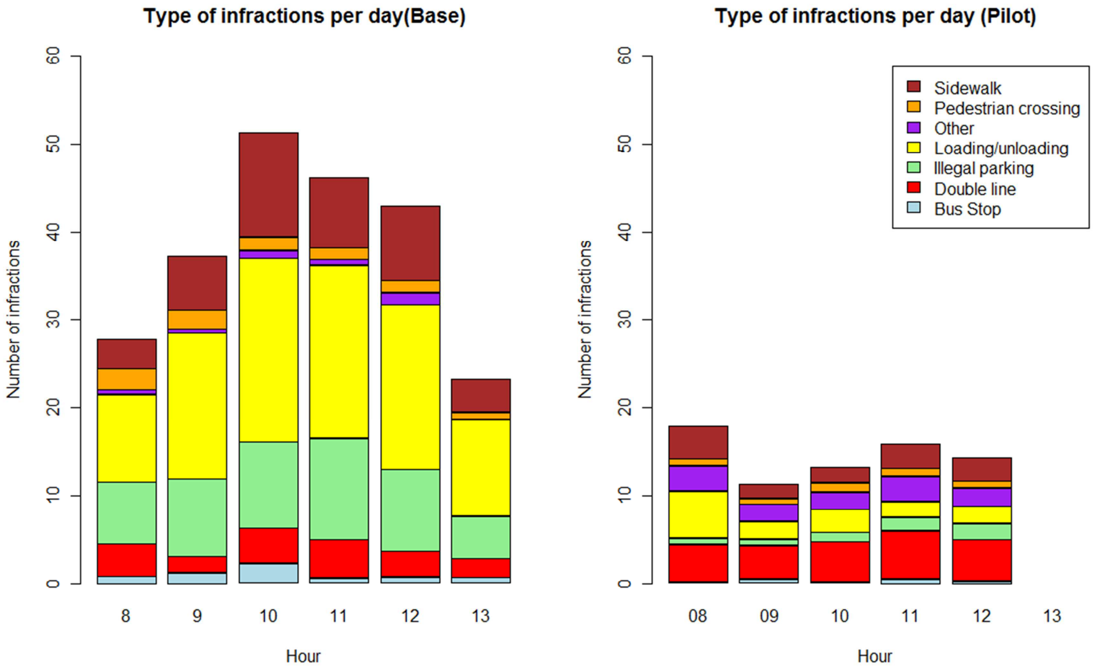


Figure 47. Average number of infractions per day (by our and type of infraction)

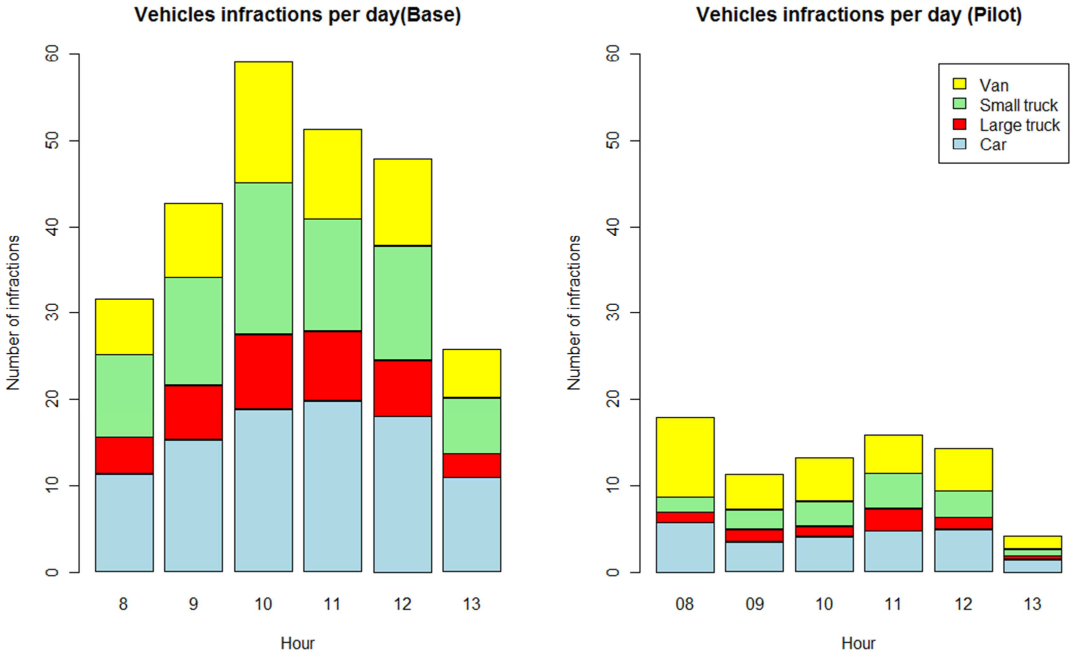


Figure 48. Average number of infractions per day (by our and type of infraction)

We observe a significant reduction of infractions, but it is not uniform. In the following tables we report the difference between baseline and pilot for all DSB:

Table 22. Infraction counting results for all DSB

Baseline	**Type of infraction**								
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Other**	**Parking for disabled**	**Pedestrian crossing**	**Sidewalk**	**Total**
Car	1,18	5,09	18,45	41,73	17,18	1,27	0,55	8,45	93,91
Large truck	1,82	3,00	8,55	6,27	2,09	0,00	3,45	11,27	36,45
Small truck	1,64	6,00	13,18	24,73	6,18	1,27	4,09	15,64	72,73
Van	1,36	5,09	11,27	24,00	4,18	1,55	1,55	6,27	55,27
Overall	**6,00**	**19,18**	**51,45**	**96,73**	**29,64**	**4,09**	**9,64**	**41,64**	**258,36**

Pilot	**Type of infraction**								
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Other**	**Parking for disabled**	**Pedestrian crossing**	**Sidewalk**	**Total**
Car	0,27	7,57	2,93	4,90	2,51	0,00	1,02	2,62	21,82
Large truck	0,27	3,80	0,67	0,07	1,73	0,00	0,07	0,87	7,47
Small truck	0,53	5,80	2,27	0,47	1,38	0,00	0,07	3,33	13,85
Van	0,20	6,74	1,27	9,24	1,58	0,00	3,18	6,65	28,86
Overall	**1,27**	**23,92**	**7,13**	**14,67**	**7,21**	**0,00**	**4,34**	**13,46**	**72,00**

Now we show those results per DSB

Table 23. Infraction counting results for General Concha

Baseline	**Type of infraction**								
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Other**	**Parking for disabled**	**Pedestrian crossing**	**Sidewalk**	**Total**
Car	0,73	0,27	3,27	13,82	15,36	1,00	0,55	3,18	38,18
Large truck	1,73	0,91	4,64	0,64	0,91	0,00	0,00	3,18	12,00
Small truck	0,91	0,27	3,00	11,27	2,73	0,64	0,82	7,18	26,82
Van	1,27	0,55	3,09	11,73	2,64	1,27	0,18	4,27	25,00
Overall	**4,64**	**2,00**	**14,00**	**37,45**	**21,64**	**2,91**	**1,55**	**17,82**	**102,00**

Pilot	**Type of infraction**								
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Other**	**Parking for disabled**	**Pedestrian crossing**	**Sidewalk**	**Total**
Car	0,07	0,73	2,53	0,00	0,87	0,00	0,07	1,80	6,07
Large truck	0,20	0,87	0,33	0,00	1,73	0,00	0,00	0,80	3,93
Small truck	0,27	2,13	1,40	0,00	1,33	0,00	0,00	3,20	8,33
Van	0,13	1,27	1,13	0,00	0,93	0,00	0,07	3,27	6,80
Overall	**0,67**	**5,00**	**5,40**	**0,00**	**4,87**	**0,00**	**0,13**	**9,07**	**25,13**

Table 24. Infraction counting results for Perez Galdós

Baseline	Type of infraction								
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Other**	**Parking for disabled**	**Pedestrian crossing**	**Sidewalk**	**Total**
Car	0,00	1,00	0,00	3,09	0,09	0,00	0,00	1,18	5,36
Large truck	0,09	1,55	0,09	1,45	0,09	0,00	1,09	2,00	6,36
Small truck	0,45	1,82	0,36	1,36	0,00	0,00	0,82	1,36	6,18
Van	0,00	1,36	0,00	2,18	0,09	0,00	0,55	0,09	4,27
Overall	**0,55**	**5,73**	**0,45**	**8,09**	**0,27**	**0,00**	**2,45**	**4,64**	**22,18**

Pilot	Type of infraction								
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Other**	**Parking for disabled**	**Pedestrian crossing**	**Sidewalk**	**Total**
Car	0,00	1,19	0,00	2,71	0,10	0,00	0,62	0,00	4,62
Large truck	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Small truck	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Van	0,00	2,14	0,00	2,19	0,00	0,00	0,67	0,38	5,38
Overall	**0,00**	**3,33**	**0,00**	**4,90**	**0,10**	**0,00**	**1,29**	**0,38**	**10,00**

Table 25. Infraction counting results for Licenciado Poza

Baseline	Type of infraction								
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Other**	**Parking for disabled**	**Pedestrian crossing**	**Sidewalk**	**Total**
Car	0,09	0,00	6,73	18,64	1,73	0,27	0,00	4,09	31,55
Large truck	0,00	0,09	2,91	2,45	1,09	0,00	2,00	6,09	14,64
Small truck	0,00	0,27	3,18	5,00	3,45	0,64	1,91	7,09	21,55
Van	0,09	0,27	4,45	3,36	1,45	0,27	0,27	1,91	12,09
Total général	**0,18**	**0,64**	**17,27**	**29,45**	**7,73**	**1,18**	**4,18**	**19,18**	**79,82**

Pilot	Type of infraction								
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Other**	**Parking for disabled**	**Pedestrian crossing**	**Sidewalk**	**Total**
Car	0,00	0,05	0,00	1,85	1,55	0,00	0,00	0,75	4,20
Large truck	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Small truck	0,00	0,00	0,00	0,00	0,05	0,00	0,00	0,00	0,05
Van	0,00	1,60	0,00	7,05	0,65	0,00	2,45	3,00	14,75
Overall	**0,00**	**1,65**	**0,00**	**8,90**	**2,25**	**0,00**	**2,45**	**3,75**	**19,00**

Table 26. Infraction counting results for General Concha

Baseline	**Type of infraction**						
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Pedestrian crossing**	**Sidewalk**	**Total général**
Car	0,36	3,82	8,45	6,18	0,00	0,00	18,82
Large truck	0,00	0,45	0,91	1,73	0,36	0,00	3,45
Small truck	0,27	3,64	6,64	7,09	0,55	0,00	18,18
Van	0,00	2,91	3,73	6,73	0,55	0,00	13,91
Total général	**0,64**	**10,82**	**19,73**	**21,73**	**1,45**	**0,00**	**54,36**

Pilot	**Type of infraction**						
Type of vehicle	**Bus Stop**	**Double line**	**Illegal parking**	**Delivery space**	**Pedestrian crossing**	**Sidewalk**	**Total général**
Car	0,20	5,60	0,40	0,33	0,33	0,07	6,93
Large truck	0,07	2,93	0,33	0,07	0,07	0,07	3,53
Small truck	0,27	3,67	0,87	0,47	0,07	0,13	5,47
Van	0,07	1,73	0,13	0,00	0,00	0,00	1,93
Total général	**0,60**	**13,93**	**1,73**	**0,87**	**0,47**	**0,27**	**17,87**

We observe that double lines increase in Santutxu, mainly those of big trucks. This results is contradictory with the expected situation, since a capacity increase should lead on a truck double lines decrease. But although small trucks remain the same, van decrease and car increase (which is a logical result) big trucks, the most able to use the DSB, are more encline to make double lines. However, illegal parking has decreased a lot (from almost 20 to 2 vehicles per day), and since it is sometimes difficult to distinguish double lines from illegal parking or to define what is a double line parking and what a small stop to wait the delivery space to be free, we can consider than overall the effects on illegal parking actions are quite positive.

In DSB evaluation, different operators carried out the infraction counting data collection. After a deep analysis of all data, we stated that several operators did not complete in an accurate way the forms. Although it was stated a control had to be done, LET had not a margin to correct this data, even if several contacts had been established. A correction process of the data has been done, but it is statistically difficult to say if they are significant.

6. Results – one system scenarios

6.1. *Delivery Space Booking*

6.1.1. Pilot characteristics and evaluation conclusion recalls

As shown in D.FL. 4.1 (Evaluation methodology) two Delivery Space Booking (DSB) system pilots have been carried out respectively in Lyon and Bilbao. Both systems were different (the Bilbao's system resulted from the adaptation of private car parking machines to allow a user's identification and illegal parking identification, and both website and in-place reservations were possible; the Lyon's DSB was based on the CVIS (Cooperative Vehicle Infrastructure Systems integrated project) framework, and allowed only website reservations, with neither in place identification nor control system).

In the Cost Benefit Analysis, three possibilities are tested:

- S1: Specific DSB machines. This scenario corresponds to Bilbao's pilot situation, where specific hardware and software for DSB was provided.
- S2: Hybrid machines for both car parking and DSB. This scenario is a more deployment situation where existing parking machines are retained and adapted to allow DSB services.
- S3: DSB without in-place reservation (only remote) and indications using variable message panels. This scenario corresponds to Lyon's pilot situation assuming that enforcement actions can be made at the same level than in Bilbao.

The main results of the evaluation are synthesised below. First, we show in the following table the direct gains for a truck on each DSB, in a deployment situation. To obtain the gains shown below, which correspond to those of Santutxu's DSB in Bilbao, we need to ensure a minimum capacity. Without what it is not possible to deduce any gain due to the saturation of parking place, even when cars are not on delivery bays.

Indicator	Without DSB	With DSB	Gap in FREILOT areas	Gap in the entire route
Travel distance (m)	147	108	-27%	-0.00%
Travel and stop time(min)	15.25	16.92	+11%	+0.6%
Fuel consumption (g)	101.4	71.5	-29%	-0.08%
CO2 emissions (g)	336	235	-30%	-0.01%
NOx emissions (g)	4.1	2.7	-34%	-0.01%

Table 27. Gains on a single DSB (from the moment the vehicle enters its influence area until the moment vehicle stops after parking). Adapted from Santutxu's pilot conclusions.

Travel time is intended on the DSB's influence area[3] (the loss is due to the security and the tranquillity drivers feel when legally parking their vehicle with respect to double line parking

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[3] A DSB influence area contains all street sections in a 60-100 m radius around the DSB centroid.

and other practices). However, another impact of DSB’s less easy to quantify (at least directly from evaluation results) is that of traffic improvement due to the usage of a coherent network of delivery bays. That effect will be further quantified, from evaluation data and a simulation with a network of DSB’s in a given city.

6.1.2. Scenario characteristics and hypotheses

In the scenario assessment it is important to define the scenarios on the same basis in order to allow a comparison between them. For this reason, it has been stated that each scenario will be defined on a hypothetic city, in which we assume a progressive development of the system to implement 25 delivery spaces within a defined zone. This zone should correspond to a city centre or a dense commercial area. It is important to note that the only way to have non negligible gains is to define a group of DSB areas that allow the drivers to use more than five on the same route (which will imply a fuel consumption gain of 0.5 % and non-negligible effects on traffic and route security and comfort).

Year 1: 1 city, 45 logistic operators, 95 numbers of vehicles, 4 delivery spaces (1 new, 3 places with 2 slots and 1 place with 3 slots. Total 9 slots

Year 2: 1 city, 200 vehicles, 6 new delivery spaces,4 places with 2 slots and 2 places with 3 slots. Total 14 slots (+9 = 23 slots)

Year 3: 1 city, 200 vehicles and 5 new delivery spaces, 4 places with 2 slots and 1 place with 3 slots. Total 11 slots (+23 = 34 slots)

Year 4: 1 city, 100 vehicles and 5 new delivery spaces with 2 slots. Total 10 slots (+34 = 44 slots)

Year 5: 1 city, 92 vehicles and 5 new delivery spaces with 2 slots. Total 10 slots (+44 = 54 slots)

TOTAL: 1 city, 687 vehicles and 25 delivery spaces (1 new) with 54 slots (4 places with 3 slots and 21 places with 2 slots)

Note: These hypotheses give a congested system, for the following reasons: 54 slots with a time range for reservation of 6h/day and a unitary reservation slot of 30 minutes result on a total capacity of 648 slots/day. However, the percentage of collected routes with small vehicles (those needing only one slot) are only 15%. Making the assumption than 40% of the slots are used by small vehicles, the maximum number of trucks using the DSB each day is 455, i.e. 66% of the total number of trucks, and this assuming that each vehicle uses a delivery space. Of course, not all vehicles need the DSB each day and some of them will use more than one DSB for each route, so this situation results on a saturation of the system or implies that a non-negligible number of vehicles will use the system only few days per week, which do not allows to make gains.

6.1.3. Economic viability analysis

First, an only economic cost-benefit analysis is made, i.e., taking into account only the economic benefits in the CBA analysis. In all three situations, two estimations are made. A 10-year forecasting analysis is made, first with basic hypotheses defined by the Bilbao’s stakeholders (coordinated by ML Cluster Euskadi) then a second analysis is made changing the various service settings to find the best service configuration to result in a rentable system.

S1 analysis

- *10-year analysis with current settings:*

Main hypotheses:

Investment costs:

- Backoffice: one main investment (software and computer machine for server, software for reservation)

- Infrastructure and civil works: installation of machines, captors and Light Emitting Diodes (LEDs) in the DSB for DSB area delimitation, display devices. One machine equipped for DSB[4].

- On board unit: card to be used on the machines (identification), one per vehicle.

Operational costs

- Backoffice: we suppose functional costs related to manpower, software updates, and maintenance related to DSB reservation system.

- Enforcement: those costs are defined by MLC from the unitary costs of policemen and the number of hours needed for the supposed enforcement controls, given by Bilbao's municipality.

- On board unit: only maintenance costs, related to changing the cards. We assume a yearly average changing rate of 15% (i.e., we suppose to change 15% of the overall number of active cards).

- The hypotheses concerning the deployment of DSBs and the vehicles using the system are the following (the system is supposed to work 14h/day):

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6+
Number of systems	4	10	15	20	25	25	25
Number of units	0	95	295	495	595	687	687
Percentage of lost/stolen OBUs	15%	15%	15%	15%	15%	15%	15%

DSB – INVESTMENT COSTS							
	AFFECTED ACTOR	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
BACK OFFICE – INITIAL INVESTMENT	Service Provider	33.000,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
INFRASTRUCTURE (Delivery space) AND CIVIL WORKS	City	20.797,57 €	31.196,36 €	25.996,97 €	25.996,97 €	25.996,97 €	0,00 €
ON BOARD UNIT INVESTMENT	Service Provider	0,00 €	475,00 €	1.000,00 €	1.000,00 €	500,00 €	460,00 €
ADVERTISING AND PUBLICITY	City	10.000,00 €	10.000,00 €	15.000,00 €	10.000,00 €	10.000,00 €	10.000,00 €
TOTAL		63.797,57 €	41.671,36 €	41.996,97 €	36.996,97 €	36.496,97 €	10.460,00 €

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[4] Data used to estimate those costs is given by GERTEK based on their costs during the pilot implementation.

DSB – OPERATIONAL COSTS							
	AFFECTED ACTOR	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
BACK OFFICE FUNCTIONAL COSTS	Service Provider	0,00 €	50.250,00 €	50.250,00 €	50.250,00 €	50.250,00 €	50.250,00 €
ENFORCEMENT	City	0,00 €	40.000,00 €	40.000,00 €	40.000,00 €	40.000,00 €	40.000,00 €
BACK OFFICE MAINTENANCE	Service Provider	0,00 €	124.695,00 €	124.695,00 €	124.695,00 €	124.695,00 €	124.695,00 €
INFRASTRUCTURE MAINTENANCE	City	0,00 €	3.200,00 €	8.000,00 €	12.000,00 €	16.000,00 €	20.000,00 €
ON BOARD UNIT MAINTENANCE	Service Provider	0,00 €	71,25 €	221,25 €	371,25 €	446,25 €	515,25 €
TOTAL		0,00 €	218.216,25 €	223.166,25 €	227.316,25 €	231.391,25 €	235.460,25 €

Regarding the possible economic benefits, only a yearly fee is considered. This fee is set to 480€/vehicle and year, including VAT, i.e. a real benefit for the public authorities of 400€/vehicle and year.

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
Number of Vehicles	0	95	295	495	595	687	687
Investment COST	63 797,57 €	41.671,36 €	41.996,97 €	36.996,97 €	36.496,97 €	10.460,00 €	10460
Operational COST	0,00 €	218.216,25 €	223.166,25 €	227.316,25 €	231.391,25 €	235.460,25 €	235.460,25 €
Total COST	63 797,57 €	259.887,61 €	265.163,22 €	264.313,22 €	267.888,22 €	245.920,25 €	245.920,25 €
Investment COST by vehicle	n.a.	438,65 €	142,36 €	74,74 €	61,34 €	15,23 €	53,13 €
Operational COST by vehicle	n.a.	2.297,01 €	756,50 €	459,22 €	388,89 €	342,74 €	342,74 €
Total COST by vehicle	**n.a.**	**3.634,52 €**	**1.432,82 €**	**984,20 €**	**808,19 €**	**753,82 €**	**395,86 €**
FEE by vehicle (without VAT)	0,00 €	400,00 €	400,00 €	400,00 €	400,00 €	400,00 €	400,00 €
Total FEE	0,00 €	38.000,00 €	118.000,00 €	198.000,00 €	238.000,00 €	274.800,00 €	274.800,00 €
Balance of total costs (for each year)	**-63 797,57 €**	**-221.887,61 €**	**-147.163,22 €**	**-66.313,22 €**	**-29.888,22 €**	**28.879,75 €**	**28.879,75 €**
Balance of operational costs (for each year)	**-63 797,57 €**	**-180.216,25 €**	**-105.166,25 €**	**-29.316,25 €**	**6.608,75 €**	**39.339,75 €**	**39.339,75 €**

We report the 10-years net present value trend (assuming a yearly updating rate of 4%) into the following graph:

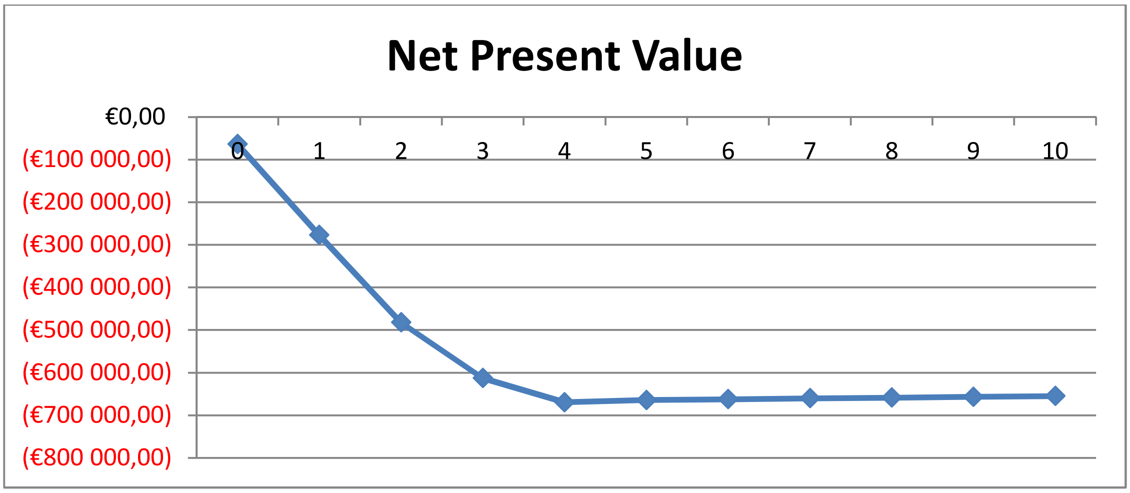

Figure 49. Net Present Value (NPV) evolution in a 10-years horizon with current settings and a yearly fee of 400 €/vehicle without VAT (i.e. 480€ with VAT)

The results show that although after year 5 the benefits are higher than the costs the return on investment trends are very slow and the money return in 10 years is far to compensate the investments. We observe also that investment costs are lower compared to operational costs but proposed fees do not allow to compensate them (only after year 4 yearly operational costs are balanced by fees), but precedent operational costs and investments represent them a non negligible quantity that is difficultly compensated (the net yearly gain after year 5 represents about 33 000 €, less than 5% of the total deficit at that moment). That means that recuperation is not possible before 30 years, which is non-realistic for a return on investment required by private actors. In order to reach a 4% of investment after 10 years, it is necessary to have an overall cost reduction about 29% or an overall revenue increasing of 40%.

- *10-year analysis changing one of more service settings:*

In a first time, we make an iterative analysis using the fee as the only variable to find the economic gains per vehicle and year the service needs to reach an IRR close to 4% within 10 years. As said above, it can be possible with an overall revenue increasing of 40%. To do this, the fee per vehicle and year has to be increased to 680 € without taxes, which means a total fee (including VAT) of about 816 €, i.e. about 68 € per vehicle and month. The system does not directly result in economical advantages for carriers (at least with a congested situation), so the fee is difficultly justifiable. However, an alternative should be an access fee to all vehicles that can finance part of the system, but this hypothesis is not explored here.

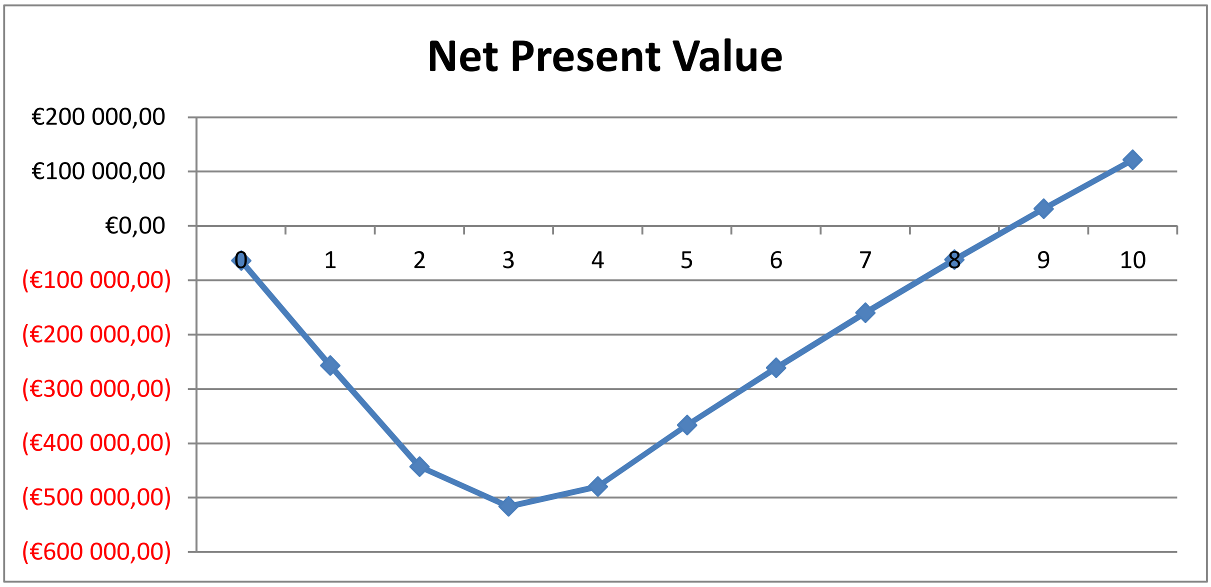

Figure 50. Cost-Benefit difference in a 10-years horizon with a fee of 680€ (without VAT) per vehicle and year

<u>S2 analysis</u>

In this situation, a hybrid machine is used, which allows to reduce the investment and operational costs.

- *10-year analysis with current settings:*

DSB – INVESTMENT COSTS

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
BACK OFFICE – INITIAL INVESTMENT	27.000,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
INFRASTRUCTURE (Delivery space) AND CIVIL WORKS	10.061,57 €	15.092,36 €	12.576,97 €	12.576,97 €	12.576,97 €	0,00 €
ON BOARD UNIT INVESTMENT	0,00 €	475,00 €	1.000,00 €	1.000,00 €	500,00 €	460,00 €
ADVERTISING AND PUBLICITY	10.000,00 €	10.000,00 €	15.000,00 €	10.000,00 €	10.000,00 €	10.000,00 €
TOTAL	47.061,57 €	25.567,36 €	28.576,97 €	23.576,97 €	23.076,97 €	10.460,00 €

DSB – OPERATIONAL COSTS

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
BACK OFFICE FUNCTIONAL COSTS	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ENFORCEMENT	0,00 €	40.000,00 €	40.000,00 €	40.000,00 €	40.000,00 €	40.000,00 €
BACK OFFICE MAINTENANCE	0,00 €	42.800,00 €	42.800,00 €	42.800,00 €	42.800,00 €	42.800,00 €
INFRASTRUCTURE MAINTENANCE	0,00 €	3.776,00 €	9.440,00 €	14.160,00 €	18.880,00 €	23.600,00 €
ON BOARD UNIT MAINTENANCE	0,00 €	71,25 €	221,25 €	371,25 €	446,25 €	515,25 €
TOTAL	0,00 €	86.647,25 €	92.461,25 €	97.331,25 €	102.126,25 €	106.915,25 €

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Over year 6
Number of Vehicles	0	95	295	495	595	687	687
Investment COST	47.061,57 €	25.567,36 €	28.576,97 €	23.576,97 €	23.076,97 €	10.460,00 €	10460
operational COST	0,00 €	86.647,25 €	92.461,25 €	97.331,25 €	102.126,25 €	106.915,25 €	106.915,25 €
Total COST	47.061,57 €	112.214,61 €	121.038,22 €	120.908,22 €	125.203,22 €	117.375,25 €	117.375,25 €
Investment COST by vehicle	495,38 €	269,13 €	96,87 €	47,63 €	38,78 €	15,23 €	33,59 €
Operational COST by vehicle	0,00 €	912,08 €	313,43 €	196,63 €	171,64 €	155,63 €	155,63 €
Total COST by vehicle	**495,38 €**	**1.591,51 €**	**654,56 €**	**454,68 €**	**381,28 €**	**360,07 €**	**189,22 €**
FEE by vehicle (without VAT)	400,00 €	400,00 €	400,00 €	400,00 €	400,00 €	400,00 €	400,00 €
Total FEE	0,00 €	38.000,00 €	118.000,00 €	198.000,00 €	238.000,00 €	274.800,00 €	274.800,00 €
Balance of total costs (for each year)	**-47.061,57 €**	**-74.214,61 €**	**-3.038,22 €**	**77.091,78 €**	**112.796,78 €**	**157.424,75 €**	**157.424,75 €**
Balance of operational costs (for each year)	**0,00 €**	**-48.647,25 €**	**25.538,75 €**	**100.668,75 €**	**135.873,75 €**	**167.884,75 €**	**167.884,75 €**

The cost-benefit analysis led to the following return on investment trend graph:

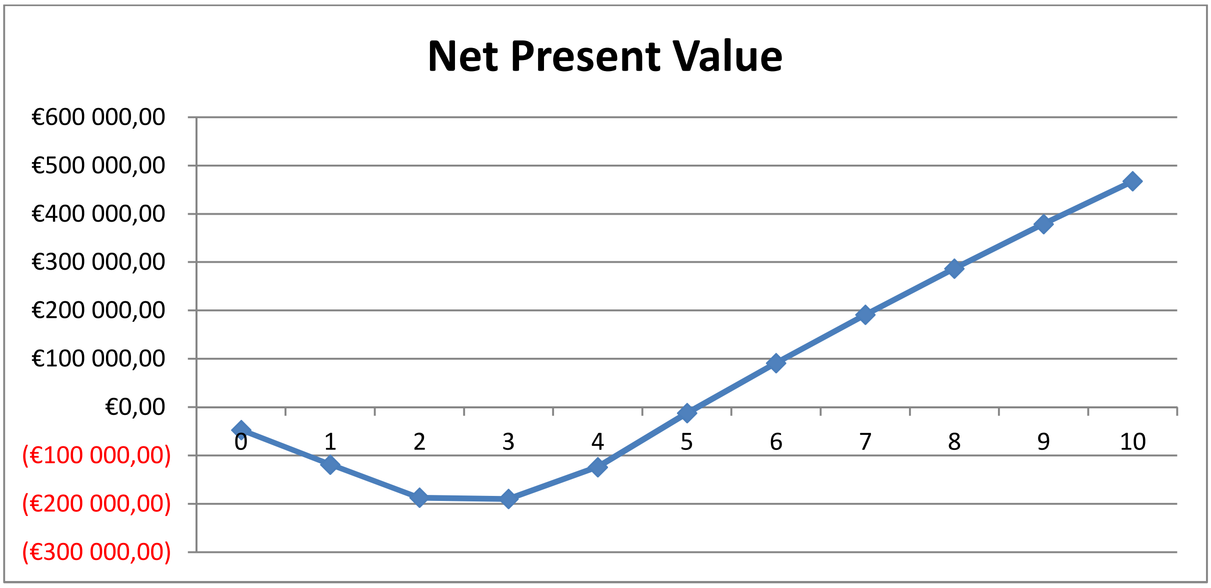

Figure 51. NPV trends in a 10-years horizon

Over 10 years, the Internal Rate of Return (IRR) is higher than 40%, whit a fee of 480€/vehicle and year including VAT. We observe that over year 3 the investment and operational costs are balanced by the income generated by the fees. In this case, we repeat the analysis in order to find a lower fee that can be justified to the transport carriers.

- *10-year analysis changing one of more service settings:*

The supposed fee allows important gains, so we can decrease it to define which is the minimum fee the public authorities need to ask for the usage of such system. In the considered scenario, a reduction of 26% in fees is possible. With an IRR target of 4% in 10 years, a fee of 280 € seems interesting, since it allows an IRR of almost 5% in 10 years. To transport carriers, this fee supposes about 336 € per vehicle and year, i.e. about 28 €/month. Remains then to find a valid justification to convince carriers to pay this fee (which can be acceptable by transport carriers but needs to be motivated). That justification will be seen in a further analysis including environmental and social benefits. Since we only changed fees, and costs remain the same as the precedent analysis, the cost tables are not reported here.

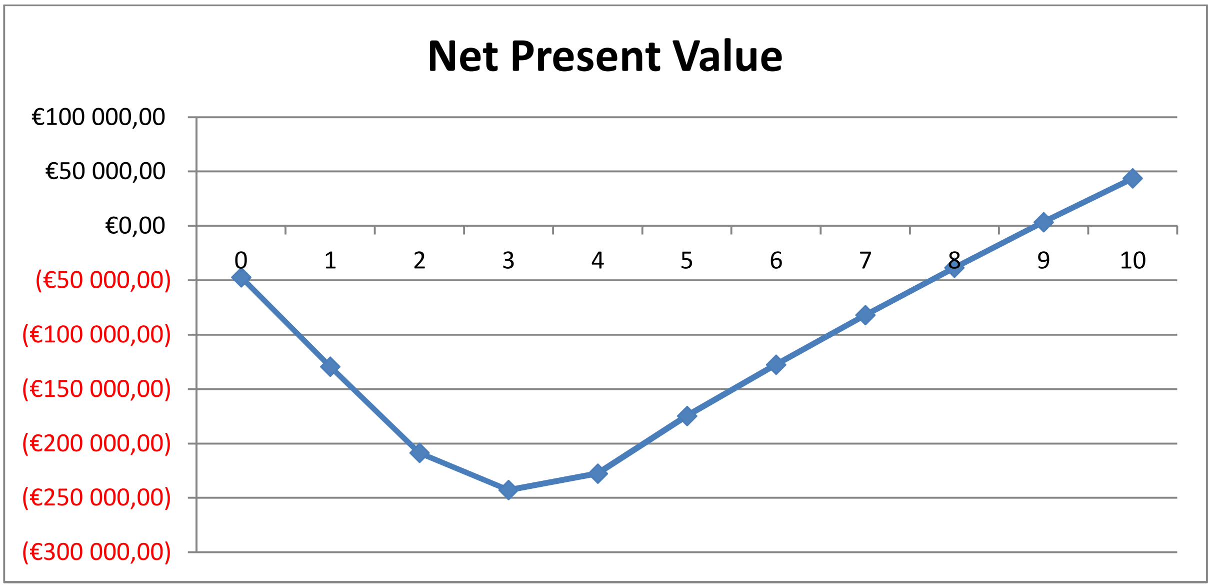

Figure 52. Cost-Benefit difference in a 10-years horizon with a fee of 360 € per vehicle and year

Although economically rentable, the proposed situation results in system saturation for the following reasons. First is the lower number of DSBs (25 DSB working 10h per day) and the number of vehicles (687), which makes that at best vehicle will visit 4 or 5 DSB. Moreover, fuel savings and congestion reduction would be efficient if a network of DSB is deployed in a zone. Following the considerations on Lyon's city centre for the deployment of intelligent delivery spaces (ALF, 2012), at least 100 DSB would be implemented. We propose then to increase the number of DSB to 100 by multiplying by 4 the number of new DSB per year and assume they are active from 6:00 a.m. to 8:00 p.m. Those new DSB will be located in the neighbourhood of the DSB hypothesised in precedent scenarios, in order to create DSB zones and allow to better managing delivery bays' availability and capacity. Moreover, a light increase of the number of vehicles is also supposed since with this configuration the capacity is not reached until 1500 are using the system. For precaution, we assume a number of vehicles of 1250, a little lower than the estimated limit.

The hypotheses concerning the deployment of DSBs and the vehicles using the system are the following (the system is supposed to work 14h/day):

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6+
Number of systems	16	40	60	80	100	100	100
Number of units	0	150	450	850	1150	1250	1250
Percentage of lost/stolen OBUs	15%	15%	15%	15%	15%	15%	15%

The cost structure is the following:

DSB – INVESTMENT COSTS							
	AFFECTED ACTOR	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
BACK OFFICE – INITIAL INVESTMENT	Service Provider	27.000,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
INFRASTRUCTURE (Delivery space) AND CIVIL WORKS	City	40.246,29 €	60.369,44 €	50.307,87 €	50.307,87 €	50.307,87 €	0,00 €
ON BOARD UNIT INVESTMENT	Service Provider	0,00 €	475,00 €	1.000,00 €	1.000,00 €	500,00 €	460,00 €
ADVERTISING AND PUBLICITY	City	10.000,00 €	10.000,00 €	15.000,00 €	10.000,00 €	10.000,00 €	10.000,00 €
TOTAL		77.246,29 €	70.844,44 €	66.307,87 €	61.307,87 €	60.807,87 €	10.460,00 €

DSB – OPERATIONAL COSTS							
	AFFECTED ACTOR	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
BACK OFFICE FUNCTIONAL COSTS	Service Provider	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ENFORCEMENT	City	0,00 €	40.000,00 €	40.000,00 €	40.000,00 €	40.000,00 €	40.000,00 €
BACK OFFICE MAINTENANCE	Service Provider	0,00 €	42.800,00 €	42.800,00 €	42.800,00 €	42.800,00 €	42.800,00 €
INFRASTRUCTURE MAINTENANCE	City	0,00 €	15.104,00 €	37.760,00 €	56.640,00 €	75.520,00 €	94.400,00 €
ON BOARD UNIT MAINTENANCE	Service Provider	0,00 €	112,50 €	337,50 €	637,50 €	862,50 €	937,50 €
TOTAL		0,00 €	98.016,50 €	120.897,50 €	140.077,50 €	159.182,50 €	178.137,50 €

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
Number of Vehicles	0	150	450	850	1150	1250	1250
Investment COST	77.246,29 €	70.844,44 €	66.307,87 €	61.307,87 €	60.807,87 €	10.460,00 €	10460
operational COST	0,00 €	98.016,50 €	120.897,50 €	140.077,50 €	159.182,50 €	178.137,50 €	178.137,50 €
Total COST	77.246,29 €	168.860,94 €	187.205,37 €	201.385,37 €	219.990,37 €	188.597,50 €	188.597,50 €
Investment COST by vehicle	495,38 €	472,30 €	147,35 €	72,13 €	52,88 €	8,37 €	48,65 €
Operational COST by vehicle	0,00 €	653,44 €	268,66 €	164,80 €	138,42 €	142,51 €	142,51 €
Total COST by vehicle	**495,38 €**	**1.541,75 €**	**652,94 €**	**428,22 €**	**342,17 €**	**342,03 €**	**191,16 €**
FEE by vehicle (without VAT)	250,00 €	250,00 €	250,00 €	250,00 €	250,00 €	250,00 €	250,00 €
Total FEE	0,00 €	37.500,00 €	112.500,00 €	212.500,00 €	287.500,00 €	312.500,00 €	312.500,00 €
Balance of total costs (for each year)	**-77.246,29 €**	**-131.360,94 €**	**-74.705,37 €**	**11.114,63 €**	**67.509,63 €**	**123.902,50 €**	**123.902,50 €**
Balance of operational costs (for each year)	**0,00 €**	**-60.516,50 €**	**-8.397,50 €**	**72.422,50 €**	**128.317,50 €**	**134.362,50 €**	**134.362,50 €**

The new analysis leads to a NPV trend resulting in an IRR of 9.2% in 10 years, which is good. However, the fee can be reduced to 250 €/vehicle and year without VAT, i.e. 300 € to obtain these trends.

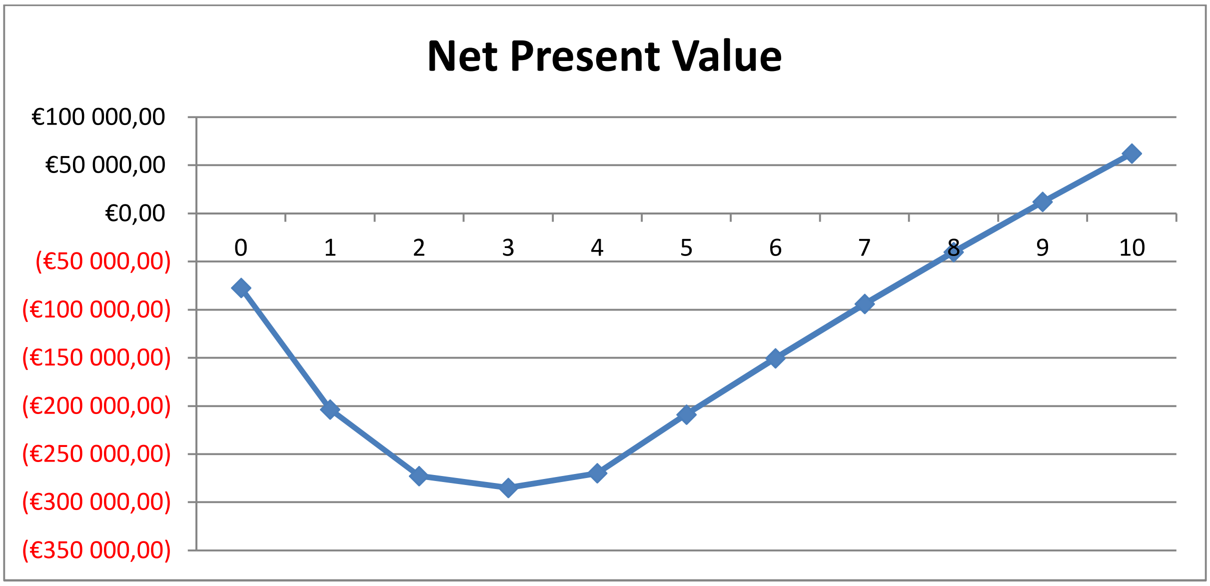

Figure 53. Cost-Benefit difference in a 10-years horizon with 100 scheduled DSB systems and a fee of 300 € per vehicle and year (including VAT)

S3 analysis

- *10-year analysis with current settings:*

Main hypotheses:

Investment costs:

- Backoffice: one main investment (software and computer machine for server, software for reservation)
- Infrastructure and civil works: installation of panels, area delimitation by painting. One panel for DSB[5].
- On board unit: none (reservation is made via a website).

Operational costs

- Backoffice: we suppose functional costs related to manpower, software updates, and maintenance related to DSB reservation system.
- Enforcement: we assume costs being similar to Bilbao since the same scheme is adopted
- On board unit: none (reservation is made via a website).

The hypotheses concerning the deployment of DSBs and the vehicles using the system are the following (the system is supposed to work 14h/day):

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[5] Data used to estimate those costs is given by THETIS based on their costs during the pilot implementation.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6+
Number of systems	16	40	60	80	100	100	100
Number of units	0	150	450	850	1150	1250	1250
Percentage of lost/stolen OBUs	The solution does not use OBUs						

DSB – INVESTMENT COSTS (BILBAO)							
	AFFECTED ACTOR	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
BACK OFFICE – INITIAL INVESTMENT	Service Provider	30 000,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
INFRASTRUCTURE (Delivery space) AND CIVIL WORKS	City	32 000,00 €	48 000,00 €	40 000,00 €	40 000,00 €	40 000,00 €	0,00 €
ON BOARD UNIT INVESTMENT	Service Provider	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ADVERTISING AND PUBLICITY	City	10 000,00 €	10 000,00 €	15 000,00 €	10 000,00 €	10 000,00 €	10 000,00 €
TOTAL		72 000,00 €	58 000,00 €	55 000,00 €	50 000,00 €	50 000,00 €	10 000,00 €

DSB – OPERATIONAL COSTS (BILBAO)							
	AFFECTED ACTOR	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
BACK OFFICE FUNCTIONAL COSTS	Service Provider	0,00 €	61 000,00 €	61 000,00 €	61 000,00 €	61 000,00 €	61 000,00 €
ENFORCEMENT	City	0,00 €	40 000,00 €	40 000,00 €	40 000,00 €	40 000,00 €	40 000,00 €
BACK OFFICE MAINTENANCE	Service Provider	0,00 €	32 000,00 €	32 000,00 €	32 000,00 €	32 000,00 €	32 000,00 €
INFRASTRUCTURE MAINTENANCE	City	0,00 €	33 024,00 €	82 560,00 €	123 840,00 €	165 120,00 €	206 400,00 €
ON BOARD UNIT MAINTENANCE	Service Provider	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
TOTAL		0,00 €	166 024,00 €	215 560,00 €	256 840,00 €	298 120,00 €	339 400,00 €

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
Number of Vehicles	0	95	295	495	595	687	687
Investment COST	72 000,00 €	150	450	850	1150	1250	1250
operational COST	0,00 €	58.000,00 €	55.000,00 €	50.000,00 €	50.000,00 €	10.000,00 €	10000
Total COST	72 000,00 €	166.024,00 €	215.560,00 €	256.840,00 €	298.120,00 €	339.400,00 €	339.400,00 €
Investment COST by vehicle	n.a.	224.024,00 €	270.560,00 €	306.840,00 €	348.120,00 €	349.400,00 €	349.400,00 €
Operational COST by vehicle	n.a.	386,67 €	122,22 €	58,82 €	43,48 €	8,00 €	40,00 €
Total COST by vehicle	**n.a.**	1.106,83 €	479,02 €	302,16 €	259,23 €	271,52 €	271,52 €
FEE by vehicle (without VAT)	0,00 €	400,00 €	400,00 €	400,00 €	400,00 €	400,00 €	400,00 €
Total FEE	0,00 €	60.000,00 €	180.000,00 €	340.000,00 €	460.000,00 €	500.000,00 €	500.000,00 €
Balance of cumulated total costs	**-47 061,57 €**	**-164.024,00 €**	**-90.560,00 €**	**33.160,00 €**	**111.880,00 €**	**150.600,00 €**	**150.600,00 €**
Balance of operational costs (for each year)	**-47 061,57 €**	**-106.024,00 €**	**-35.560,00 €**	**83.160,00 €**	**161.880,00 €**	**160.600,00 €**	**160.600,00 €**

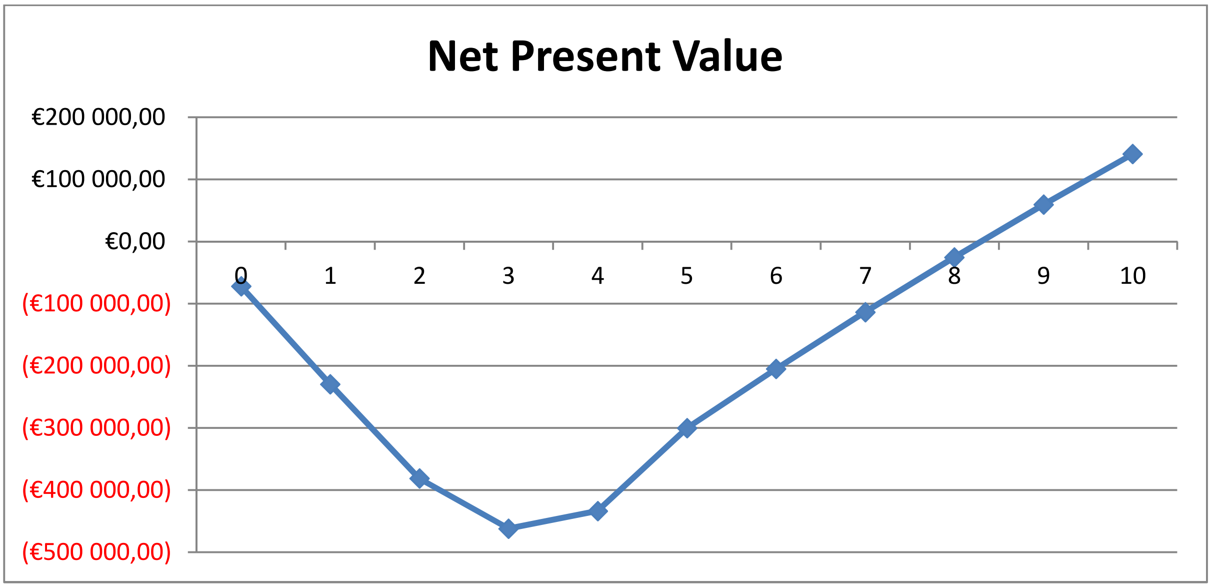

Figure 54. Cost-Benefit difference in a 10-years horizon with the panel solution

Since the obtained IRR over 10-years is higher than 4% (more precisely, 4.6%), we can retain that current settings make the system rentable for S3. The retained fee (400 € without VAT, i.e. 480 € with VAT) is higher than in scenario 2. Moreover, and taken into account the developments on Lyon's pilot, evaluation results show that although the technology is on maturity stage, the organization around it is less assessed that in Bilbao (many questions concerning governance and coordination must still be defined to make the system really operational). For those reasons, the remaining analyses are made using Bilbao's system.

6.1.4. Sensitivity analysis

Once a suitable scenario is selected (in this case, S2 with best configurations) it is important to test the sensitivity of the different variables. For this reason, we make a second simulation changing the values of each group of variables. We assume a margin of 10% in cost estimations, i.e. we consider that each group of costs is increased or decreased by 10%, either investment (infrastructure and civil works, on board unit acquisition, advertising) or operational (enforcement, back office maintenance, infrastructure maintenance). Other costs like back office investment or on board unit maintenance are very small with respect to the total costs, so their effects can be considered as negligible.

+10%	**Total Costs**	**Benefits**	**B-C**	**10 years IRR**
Initial Situation	**1 986 273 €**	**2 102 820 €**	**116 547 €**	**5,87%**
Invesment Cost				
INFRASTRUCTURE (Delivery space) AND CIVIL WORKS	2 011 427 €	2 102 820 €	91 393 €	**4,54%**
ON BOARD UNIT INVESTMENT	1 986 847 €	2 102 820 €	115 973 €	**5,84%**
ADVERTISING AND PUBLICITY	1 997 773 €	2 102 820 €	105 047 €	**5,26%**
Operational Cost				
ENFORCEMENT	2 026 273 €	2 102 820 €	76 547 €	**3,78%**
BACK OFFICE MAINTENANCE	2 029 073 €	2 102 820 €	73 747 €	**3,63%**
INFRASTRUCTURE MAINTENANCE	2 061 416 €	2 102 820 €	41 404 €	**2,01%**

-10%	Total Costs	Benefits	B-C	10 years IRR
Initial Situation	**1 986 273 €**	**2 102 820 €**	**116 547 €**	**5,87%**
Invesment Cost				
INFRASTRUCTURE (Delivery space) AND CIVIL WORKS	1 961 119 €	2 102 820 €	141 701 €	**7,23%**
ON BOARD UNIT INVESTMENT	1 985 700 €	2 102 820 €	117 120 €	**5,90%**
ADVERTISING AND PUBLICITY	1 974 773 €	2 102 820 €	128 047 €	**6,48%**
Operational Cost				
ENFORCEMENT	1 946 273 €	2 102 820 €	156 547 €	**8,04%**
BACK OFFICE MAINTENANCE	1 943 473 €	2 102 820 €	159 347 €	**8,20%**
INFRASTRUCTURE MAINTENANCE	1 911 131 €	2 102 820 €	191 689 €	**10,03%**

We observe that the most sensible variables are operational costs. Since in technological projects the underestimations are most important than in infrastructural ones, we define the back office maintenance as the critical variable.

6.1.5. Overall cost-benefit analysis

In this second study, environmental and social costs are included. From the evaluation, we observe that environmental and social costs for transport carriers are negligible, since the DSB are few and it is difficult to find a synergy. However, for the city, when positioning the DSB in a limited traffic zone (LTZ), the usage of these systems can be in synergy to the access conditions to the LTZ, and then the traffic nuisances reduction is possible to be taken into account. In this analysis we take the best configuration for S2 (100 DSB with hybrid machines, leading to CBA summarized in Figure 53) and S3.

- *Transport company's viewpoint*

First, it is important to quantify the benefits of a DSB for a transport company. In this case, we can identify four direct benefits for a carrier:

  - Fuel savings, directly translated into economic gains (money savings related to fuel consumption).
  - Time savings, also directly translated into economic gains (money savings related to timetabling and working hours).
  - Distance savings, indirectly translated into economic gains (money savings related to vehicle usage).
  - CO_2 savings, which can be related to economic gains if a Carbon Tax is assumed.

Distance savings are small compared to each route total distance and the vehicle's life, so the impacts on vehicle usage (wheels, brakes) are assumed as negligible. Time savings are also negligible (less than 2 minutes per stop, less than the data collection incertitude threshold, although the trend is to increase slightly times, but not enough to result in significant changes on daily working hours). So the only two variables that result in cost savings are fuel consumption and CO_2 emissions.

We assume that the DSB areas will be created in order to consent the loading and unloading operations for carriers that are not DSB customers, i.e., to be developed in a non-congested situation. For this reason we assume a development of 100 DSB systems, with a daily time range of 14 hours (from 6:00 a.m. to 8:00 p.m), in order to allow a re-equilibration of the system and maximize the usage of each delivery bay. We extrapolate the results of Bilbao's DSB evaluation with a small calibration concerning small vehicles, the category the less concerned by the system (their characteristics and delivery behaviour show the need of stopping even no place is available and the possibility to make double lines without significantly perturbing the traffic and the environment). In this context, we assume a unitary fuel and CO_2 savings per vehicle per DSB stop as follows:

Vehicle type	Fuel savings (ml)	CO_2 savings (g)
Van	0	0
Small truck	32	82
Big truck	40	101

Table 28 - Fuel and CO_2 savings for DSB in a deployment situation

We make the following assumptions:

1. The deployment of the DSB allow an average usage of the system, per vehicle, as follows:
   a. First year (16 DSB): 5 stops/route at DSB.
   b. Second year (40 DSB): 8 stops/route at DSB.
   c. Third year and more: 11 stops/route at DSB.

2. Savings related to double line avoiding are negligible for drivers in terms of fuel consumption and CO_2 emissions. However, a speed gain related to congestion decreasing can be assumed. This gain is estimated to be about 2 km/h in average in the considered area, i.e. an average gain in route of 20 min., corresponding to a time savings of 6% with respect to total travel time.

3. Fuel savings are estimated in gram, then converted into liter using an average volumetric mass for fuel of 750 g/l. Moreover, a fuel cost of 1.3 €/l is assumed (this is the current value in France, according to CNR (2012), it can be updated to the current value for each country).

4. Concerning CO_2, we assume a carbon tax for each transport carrier. Although the current value is 17€/ton, we aim to set it to 100 €/ton, according to the last European Considerations (French Ministery of Land Use and Transport, 2005). In this configuration, a carrier having a standard route (see Pluvinet et al., 2012, for more information about routes using DSB in Bilbao) would pay about 1175 €/truck each year (for trucks making urban distribution as those of DSB pilot). On the another hand, the direct benefits are small since the gain of CO_2 and the current carbon prices give an average gain of 16 €/truck each year.

The benefit table for the transport carrier is the following:

Type of gain	Stakeholder	Economic gain (€/year)
Vehicle usage	Transport operator	0 €/year
Time savings	Transport operator	350 €/year
Fuel savings	Transport operator	85 €/year
CO_2 reduction	Transport operator	15 €/year
Total savings	Transport operator	450 €/year

Table 29. Benefits for transport carriers (DSB)

Supposing a Fee of 250 €/vehicle each year, after year 5 and that each transport carrier would have an average benefit of 450 €/vehicle each year leads to a potential gain of 200 € per vehicle and year, mainly due to the congestion reduction (= time savings). Remains then to evaluate the gains for the city but the impacts for carriers are positive mainly due to a global effect: illegal parking reduction and better distribution of parking due to urban goods transport and loading/unloading.

- *Collective (Public authorities') viewpoint*

From the collective viewpoint, i.e. that of the public authority concerned by the implementation of the DSB system, costs are those of the economic analysis made above, from what S2 was selected. To the chosen fee, other benefits can be defined, mainly related to congestion and CO_2 reductions:

- The most important benefit derives from congestion reduction. That benefit does not derive directly from evaluation but needs a global simulation to estimate them. To do this, we estimate the CO_2 emissions of global traffic (people and freight) on the considered area. To do this, we consider a speed increase of 1 km/h for each vehicle. To estimate the traffic considered, we use the modelling framework proposed in Gonzalez-Feliu et al. (2012) to estimate the total travelled distances in the area by a subset of traffic (about 60% of the total traffic) and the IMPACT software (ADEME, 2003) to estimate global emissions. We do not use the framework of evaluation because we need to simulate average behaviours for an overall set of vehicles (related to both people and freight transport) and in the considered situation the driving behaviour does not change, only the average speeds, so the IMPACT software is more suitable to those simulations. All simulations are applied to a hypothetical city on the basis of Lyon's data.

- To those benefits, we add environmental benefits of FREILOT trucks, already estimated in precedent section.
- Other benefits (fuel consumption, social benefits) are difficult to estimate. Fuel consumption of FREILOT vehicles is negligible when compared to the total traffic's fuel consumption, and qualitative questionnaires do not allow estimating quantitative benefits. Moreover, time gains are difficult to be converted into quantitative benefits for public authorities, and security issues should need complementary data that has not been collected due to the difficulty to capture it (number of incidents, nature of incidents).

In the CBA, costs remain the same as that of the best S2 configuration. Benefits change, since environmental impacts are traduced to economic values:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Over year 6
FEE by vehicle	170,00 €	170,00 €	170,00 €	170,00 €	170,00 €	170,00 €	170,00 €
Total FEE	0,00 €	25.500,00 €	76.500,00 €	144.500,00 €	195.500,00 €	212.500,00 €	212.500,00 €
CO2 gains-Traffic	0,00 €	2.416,07 €	5.315,35 €	7.248,21 €	8.697,85 €	9.664,28 €	9.664,28 €
CO2 gains-Freight	0,00 €	3.750,00 €	11.250,00 €	21.250,00 €	28.750,00 €	28.750,00 €	31.250,00 €
Total benefits	0,00 €	31.666,07 €	93.065,35 €	172.998,21 €	232.947,85 €	250.914,28 €	253.414,28 €
ROI	**-77.246,29 €**	**-137.194,87 €**	**-94.140,01 €**	**-28.387,16 €**	**12.957,48 €**	**62.316,78 €**	**64.816,78 €**
Balance of operational costs	**0,00 €**	**-66.350,43 €**	**-27.832,15 €**	**32.920,71 €**	**73.765,35 €**	**91.731,78 €**	**75.276,78 €**

Socio-economic benefits being about 20% of economic benefits (fees), the contribution of environmental impacts is not negligible. Indeed, an IRR of 4.6% is reached with a fee of 204 € per vehicle and year (including V.A.T.), i.e. a unitary income of 170 € per vehicle and year. Without taking into account socio-economic impacts, the needed fee was 360 € per vehicle and year, so the public authorities can reduce that fee of more than 40%, resulting on a monthly cost for carriers of 17 € per vehicle, which is affordable. The difference between those two fees can be obtained by the CO2 emission gains that public authorities will earn in a hypothesis of a carbon tax that public authorities had to pay.

6.1.6. Application to different cities

Concerning DSB, it has been proved in the evaluation that the system acts very locally. So the impact of the systems does not depend on the city size but on the DSB network configuration (in term of size and complementarity). However, we can define different network configurations indirectly related to the size of the city in number of inhabitants.

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
City of 1.000.000 inhabitants (as Bilbao)- 50 DSB	Number of DSBs	0	8	20	30	40	50
	Investment costs	57 123 €	40 799 €	41 413 €	36 603 €	36 068,93 €	10 510 €
	Operational costs	0 €	90 444 €	101 961 €	111 618 €	121 196 €	130 712 €
	Total costs	**57 123 €**	**131 243 €**	**143 375 €**	**148 222 €**	**157 264 €**	**141 222 €**
City of 2.000.000 inhabitants (as Lyon)- 100 DSB	Number of DSBs	0	16	40	60	80	100
	Investment costs	77 246 €	71 119 €	66 807 €	62 307 €	61 807,85 €	10 500,00 €
	Operational costs	0 €	98 016 €	120 897 €	140 077 €	159 182 €	178 137 €
	Total costs	**77 246 €**	**169 135 €**	**187 705 €**	**202 385 €**	**220 990 €**	**188 637 €**
City of 3.000.000 inhabitants (as Madrid)- 200 DSB	Number of DSBs	0	32	80	120	160	200
	Investment costs	117 492 €	132 238 €	118 615 €	114 615 €	113 615 €	11 000 €
	Operational costs	0,00 €	113 233 €	158 995 €	197 355 €	235 565 €	273 475 €
	Total costs	**117 492 €**	**245 471 €**	**277 610 €**	**311 970 €**	**349 180,70 €**	**284 475,00 €**

Table 30. Costs of implementing the DSB systems on cities of different size

To those costs it is important to estimate the benefits, which are proportional to the number of vehicles using it. However, and taking into account the characteristics of urban routes (Pluvinet et al., 2012), the quality of the evaluation data and the hypotheses made for evaluation and CBA, it is difficult to see which are the real impacts of the network characteristics, so an in-depth IRR analysis has in our opinion no place here. To do this, it is important to have real data on the area of application then taking into account the basic results (see D.FL. 4.2 and the above parts of section 3.1. of the present deliverable for more information) and transposing them to the city where the DSB deployment aims to be assessed.

6.2. Energy Efficient Intersection Control

6.2.1. Pilot characteristics and evaluation conclusion recalls

As shown in D.FL. 4.1 (Evaluation methodology) three different EEIC approaches have been piloted. In Helmond and Krakow, the Peek cooperative intersection priority system has been piloted. In Lyon, due to legislative and technical performance reasons, a different collaborative system has been piloted. Finally, also in Lyon, a coordinated system (green wave) has also been piloted. Both collaborative systems are similar and give to equipped trucks the green light if the cycle constraints are respected. To respect those conditions, an advised speed is given to the driver, in order to make the truck arrive to the light at a moment where it is green, accelerating or retarding when needed.

The main results of the evaluation are synthesised below. Note that the benefit of this type of intersection control largest when several connected intersections are travelled though by a vehicle. For this reason, it seems suitable to use them for access to city centres or other activity areas (commercial centres, industrial zones, etc.), so the evaluation results have been aggregated to estimate the effects of intersection control in such situations.

Indicator	Without EEIC	With EEIC	Gap in FREILOT areas
Travel speed (km/h)	34	38	23%
Travel time(s)	19	17	-11%
Fuel consumption (g)	15	14	-7%
CO2 emissions (g)	404	375	-7%
NOx emissions (g)	2.5	2.3	-9%

Table 31. Gains at each intersection (influence area of 180 m: 120 before and 60 after) for a vehicle traveling into or out of the city centre. Results extrapolated from Route de Lyon and Helmond's evaluation conclusions

6.2.2. Scenario characteristics and hypotheses

In the Cost Benefit Analysis, three possibilities are tested:

- S1: Cooperative system in the BUA[6] situation. In this case, current systems are supposed operational and applied to access ways of cities in off-peak hours (during peak hours, the system can decrease the overall efficiency of intersections, as seen on Lyon's pilot).
- S2: Cooperative system with priority lanes. In this case, current systems are supposed operational and applied to access ways of cities, with the addition of priority lanes to allow the usage also in peak hours.

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[6] Business as usual

- S3: Coordinated system, i.e. green waves on the same axes as on S1 and S2.

To set the scenarios on the same basis in order to allow a comparison between them, each scenario will be defined on a hypothetic city, in which we assume a progressive development of the system to implement 150 intersections are equipped with the EEIC systems. That hypothesis represents a situation where the main axes of a city will propose the EEIC service. In this way, the most important benefits of EEIC can be obtained if vehicles travelling from one part of the city to another use the EEIC axes. Moreover, systems can concentrate the freight traffic on defined axes liberating other roads or motorways for a better commodity of people. The increasingly implementation of the system is the following:

Year 1: 1 city, 200 vehicles, 25 equipped intersections.
Year 2: 1 city, 300 vehicles, 40 equipped intersections.
Year 3: 1 city, 300 vehicles, 40 equipped intersections.
Year 4: 1 city, 300 vehicles, 30 equipped intersections.
Year 5: 1 city, 200 vehicles, 15 equipped intersections.
TOTAL: 1 city, 1300 vehicles and 150 equipped intersections.

As for DSB, the proposed hypotheses aim to provide a network effect having as consequence a major usage of the EEIC axes by trucks and to free other axes for people transport.

6.2.3. Economic viability analysis

First, an only economic cost-benefit analysis is made. In all three situations, two estimations are made. A 10-years forecasting analysis is made, first with basic hypotheses defined by the involved stakeholders (Grand Lyon, City of Helmond, Peek Traffic) then a second analysis is made changing the various service settings to find the best service configuration to result in an economically viable system.

S1 analysis

Since the method is clearly illustrated in the DSB case, we propose a CBA of the best settings for each scenario. Moreover, in EEIC two sources of cost for the logistics operators are seen: a fee and the cost of the on-board unit that has to be installed on the truck. For this reason, two points of view need to be analysed: first, the collective one, and then that of the transport carrier.

Main hypotheses:

Investment costs:

- Back office: one main investment (software and computer machine for server, software for reservation). We include in back office also off-board unit costs, assuming one installation per intersection

- Infrastructure and civil works: installation of systems on intersections.

- On board unit: a commercial solution is supposed, and it is supposed to be paid by the transport carrier.

Operational costs

- Back office: we suppose functional costs related to manpower, software updates, and maintenance related to off-board units.

- Enforcement: no need to make the system work.

- On board unit: costs estimated by technology construction (Peek Traffic and Grand Lyon’s suppliers).

- The hypotheses concerning the deployment of EEICs and the vehicles using the system are the following (the system is supposed to work from 10h00 to 12h00, from 14h00 to 16h00 and from 20h00 to 6h00):

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6+
Number of systems	25	65	105	135	150	150	150
Number of units	0	200	500	800	1100	1300	1300

In the following table we can see the costs and direct benefits for the public administration:

EEIC – INVESTMENT COSTS						
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5 and more**
BACK OFFICE – INITIAL INVESTMENT	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
INFRASTRUCTURE (intersection) AND CIVIL WORKS	350 287,50 €	560 460,00 €	560 460,00 €	420 345,00 €	210 172,50 €	0,00 €
ADVERTISING AND PUBLICITY	10 000,00 €	10 000,00 €	0,00 €	0,00 €	0,00 €	0,00 €
TOTAL	360 287,50 €	570 460,00 €	560 460,00 €	420 345,00 €	210 172,50 €	0,00 €

EEIC – OPERATIONAL COSTS						
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5 and more**
BACK OFFICE FUNCTIONAL COSTS	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ENFORCEMENT	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
BACK OFFICE MAINTENANCE	0,00 €	1 900,00 €	1 900,00 €	1 900,00 €	1 900,00 €	1 900,00 €
INFRASTRUCTURE MAINTENANCE	0,00 €	20 000,00 €	52 000,00 €	84 000,00 €	108 000,00 €	120 000,00 €
TOTAL	0,00 €	20 400,00 €	52 400,00 €	84 400,00 €	108 400,00 €	120 400,00 €

As for DSB, the first analysis seeks to find the minimum fee the system needs to be economically viable. In this case, a yearly fee of 400 € (with VAT) per vehicle is supposed, i.e. a net income of 333 € per vehicle each year.

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
Number of Vehicles	0	200	500	800	1100	1300	1300
Investment COST	392 981,00 €	622 769,60 €	612 769,60 €	459 577,20 €	229 788,60 €	0,00 €	0,00 €
Operational COST	0,00 €	21 900,00 €	53 900,00 €	85 900,00 €	109 900,00 €	121 900,00 €	121 900,00 €
Total COST	392 981,00 €	644 669,60 €	666 669,60 €	545 477,20 €	339 688,60 €	121 900,00 €	121 900,00 €
Investment COST by vehicle	n.a.	1 964,91 €	1 245,54 €	765,96 €	417,80 €	176,76 €	0,00 €
Operational COST by vehicle	n.a.	109,50 €	107,80 €	107,38 €	99,91 €	93,77 €	93,77 €
Total COST by vehicle	**n.a.**	**2 074,41 €**	**1 353,34 €**	**873,34 €**	**517,71 €**	**270,53 €**	**93,77 €**
FEE by vehicle (without VAT)	0,00 €	333,00 €	333,00 €	333,00 €	333,00 €	333,00 €	333,00 €
Total FEE	0,00 €	66 600,00 €	166 500,00 €	266 400,00 €	366 300,00 €	432 900,00 €	432 900,00 €
Balance of cumulated total costs	**-392 981,00 €**	**-348 281,00 €**	**-858 450,60 €**	**-1 290 720,20 €**	**-1 493 897,40 €**	**-1 412 686,00 €**	**-1 101 686,00 €**
Balance of operational costs (for each year)	**-392 981,00 €**	**44 700,00 €**	**112 600,00 €**	**180 500,00 €**	**256 400,00 €**	**311 000,00 €**	**311 000,00 €**

We report the 10-years net present value trend (assuming a yearly updating rate of 4%) into the following graph:

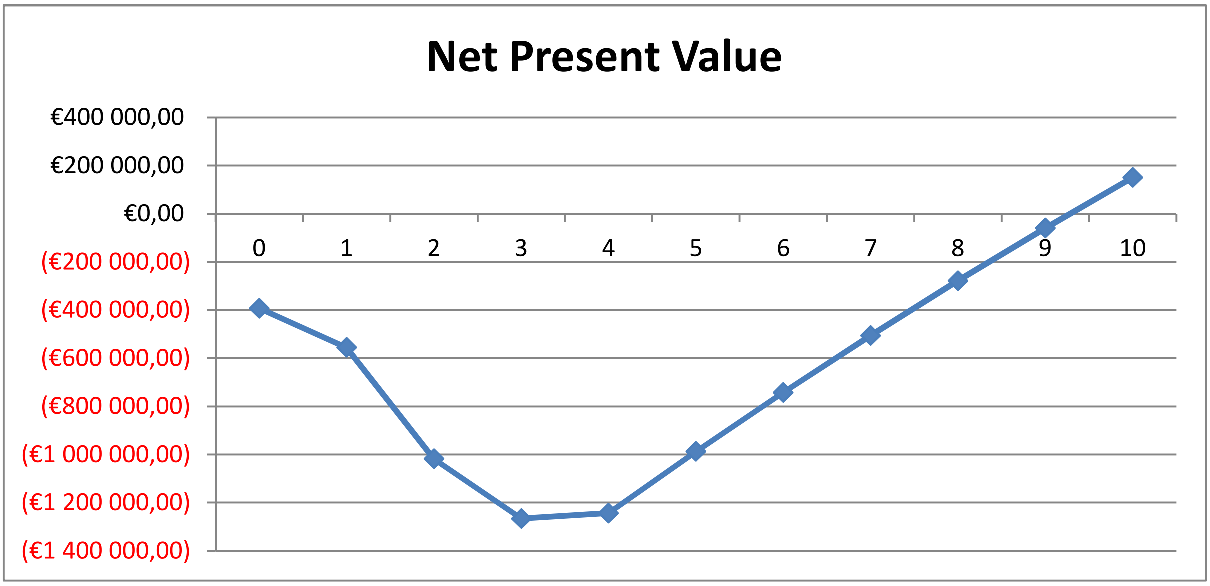

Figure 55. NPV evolution in a 10-years horizon with current settings and a yearly fee of 400 €/vehicle with VAT

The results confirm that the service can reach a balance after 10 years (IRR after 10 years: 4.3%). However, we observe that investment costs are more important in this case that in DSB services, which means that operationally, the system is still viable at year 1, and after all investments are made, the benefits allow to quickly increase the NPV.

S2 analysis

In this situation, the cost structure is almost the same as S1, the only changes are seen on infrastructure, since priority lanes need to indicated. However, those costs are mainly related to small civil works like painting and signalling, so they represent a small increase of the infrastructural costs.

In the following table we can see the costs and direct benefits for the public administration:

EEIC – INVESTMENT COSTS						
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5 and more**
BACK OFFICE – INITIAL INVESTMENT	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
INFRASTRUCTURE (intersection) AND CIVIL WORKS	467 050,00 €	747 280,00 €	747 280,00 €	560 460,00 €	280 230,00 €	0,00 €
ADVERTISING AND PUBLICITY	10 000,00 €	10 000,00 €	0,00 €	0,00 €	0,00 €	0,00 €
TOTAL	477 050,00 €	757 280,00 €	747 280,00 €	560 460,00 €	280 230,00 €	0,00 €

EEIC – OPERATIONAL COSTS						
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5 and more**
BACK OFFICE FUNCTIONAL COSTS	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ENFORCEMENT	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
BACK OFFICE MAINTENANCE	0,00 €	400,00 €	400,00 €	400,00 €	400,00 €	400,00 €

INFRASTRUCTURE MAINTENANCE	0,00 €	20 000,00 €	52 000,00 €	84 000,00 €	108 000,00 €	120 000,00 €
TOTAL	0,00 €	20 400,00 €	52 400,00 €	84 400,00 €	108 400,00 €	120 400,00 €

As for DSB, the first analysis seeks to find the minimum fee the system needs to be economically viable. In this case, a yearly fee of 460 € (with VAT) per vehicle is needed to reach an IRR of 4.4% in 10 years.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Over year 6
Number of Vehicles	0	200	500	800	1100	1300	1300
Investment COST	477 050,00 €	757 280,00 €	747 280,00 €	560 460,00 €	280 230,00 €	0,00 €	0,00 €
Operational COST	0,00 €	21 900,00 €	53 900,00 €	85 900,00 €	109 900,00 €	121 900,00 €	121 900,00 €
Total COST	477 050,00 €	779 180,00 €	801 180,00 €	646 360,00 €	390 130,00 €	121 900,00 €	121 900,00 €
Investment COST by vehicle	n.a.	2 385,25 €	1 514,56 €	934,10 €	509,51 €	215,56 €	0,00 €
Operational COST by vehicle	n.a.	109,50 €	107,80 €	107,38 €	99,91 €	93,77 €	93,77 €
Total COST by vehicle	**n.a.**	**2 494,75 €**	**1 622,36 €**	**1 041,48 €**	**609,42 €**	**309,33 €**	**93,77 €**
FEE by vehicle (without VAT)	0,00 €	384,00 €	384,00 €	384,00 €	384,00 €	384,00 €	384,00 €
Total FEE	0,00 €	76 800,00 €	192 000,00 €	307 200,00 €	422 400,00 €	499 200,00 €	499 200,00 €
Balance of cumulated total costs	**-477 050,00 €**	**-422 150,00 €**	**-1 041 330,00 €**	**-1 567 310,00 €**	**-1 815 270,00 €**	**-1 718 200,00 €**	**-1 340 900,00 €**
Balance of operational costs (for each year)	**-477 050,00 €**	**54 900,00 €**	**138 100,00 €**	**221 300,00 €**	**312 500,00 €**	**377 300,00 €**	**377 300,00 €**

We report the 10-years net present value trend (assuming a yearly updating rate of 4%) into the following graph:

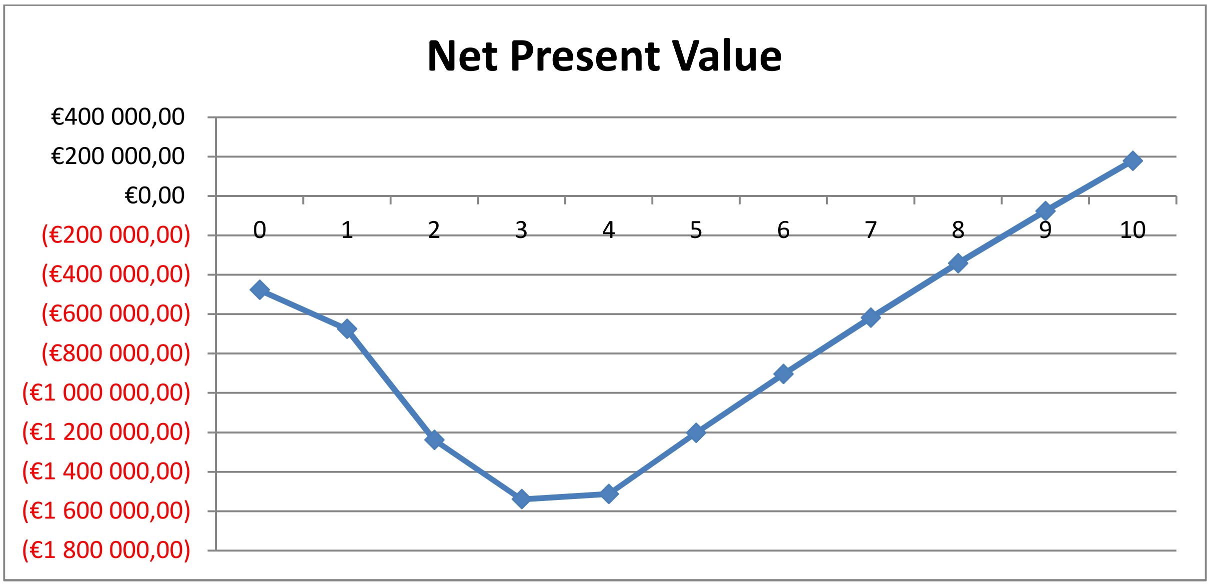

Figure 56. NPV evolution in a 10-years horizon with current settings and a yearly fee of 460 €/vehicle with VAT

The results are very close to those of S1, but the needed fee is higher (460 € per vehicle and year) because investment costs to provide reserved freight lines are added to EEIC investment costs (onboard units and traffic lights).

S3 analysis

In S3 (the green wave scenario) we make the hypothesis that no fee is asked. Moreover, the potential users are not only all trucks passing through the considered intersections but also other cars and trucks that a green wave can attract. We consider in a first time a number of trucks equal to those of S1 and S2 to compare all three scenarios.

The costs of the green wave system are the following:

EEIC – INVESTMENT COSTS							
	AFFECTED ACTOR	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
BACK OFFICE – INITIAL INVESTMENT	Service Provider	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
INFRASTRUCTURE (intersection) AND CIVIL WORKS	City	137 132,56 €	219 412,10 €	219 412,10 €	164 559,08 €	82 279,54 €	0,00 €
ADVERTISING AND PUBLICITY	City	10 000,00 €	10 000,00 €	0,00 €	0,00 €	0,00 €	0,00 €
TOTAL		147 132,56 €	229 412,10 €	219 412,10 €	164 559,08 €	82 279,54 €	0,00 €

EEIC – OPERATIONAL COSTS							
	AFFECTED ACTOR	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
BACK OFFICE FUNCTIONAL COSTS	Service Provider	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ENFORCEMENT	City	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
BACK OFFICE MAINTENANCE	Service Provider	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
INFRASTRUCTURE MAINTENANCE	City	0,00 €	2 500,00 €	6 500,00 €	10 500,00 €	13 500,00 €	15 000,00 €
TOTAL		0,00 €	2 500,00 €	6 500,00 €	10 500,00 €	13 500,00 €	15 000,00 €

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
Number of Vehicles	0	200	500	800	1100	1300	1300
Investment COST	147 132,56 €	229 412,10 €	219 412,10 €	164 559,08 €	82 279,54 €	0,00 €	0,00 €
Operational COST	0,00 €	2 500,00 €	6 500,00 €	10 500,00 €	13 500,00 €	15 000,00 €	15 000,00 €
Total COST	147 132,56 €	231 912,10 €	225 912,10 €	175 059,08 €	95 779,54 €	15 000,00 €	15 000,00 €
Investment COST by vehicle	n.a.	735,66 €	458,82 €	274,27 €	149,60 €	63,29 €	0,00 €
Operational COST by vehicle	n.a.	12,50 €	13,00 €	13,13 €	12,27 €	11,54 €	11,54 €
Total COST by vehicle	**n.a.**	**748,16 €**	**471,82 €**	**287,39 €**	**161,87 €**	**74,83 €**	**11,54 €**
FEE by vehicle (without VAT)	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
Total FEE	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
Balance of cumulated total costs	**-147 132,56 €**	**-149 632,56 €**	**-385 544,66 €**	**-615 456,77 €**	**-793 515,84 €**	**-890 795,38 €**	**-905 795,38 €**
Balance of operational costs (for each year)	**0,00 €**	**-2 500,00 €**	**-6 500,00 €**	**-10 500,00 €**	**-13 500,00 €**	**-15 000,00 €**	**-15 000,00 €**

The NPV evolution is obviously negative (no economic savings are considered in this first approach). We observe that the investment costs are near 700 000 € but the operational costs are very small (about 15 000 €/year, easily compensable by an optimization of the traffic management service of a city).

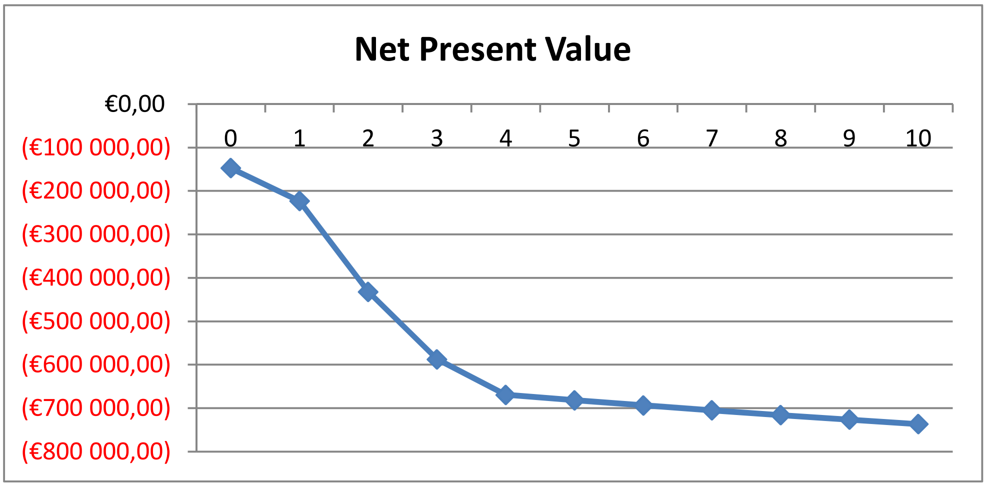

Figure 57. NPV evolution in a 10-years horizon with a green wave and no fee

After that, it is important to see if the environmental economies for the city justify this type of investment.

6.2.4. Sensitivity analysis

Once a suitable scenario is selected (in this case, S2 with best configurations) it is important to test the sensitivity of the different variables. For this reason, we make a second simulation changing the values of each group of variables. We assume a margin of 10% in cost estimations, i.e. we consider that each group of costs is increased or decreased by 10%, either investment (infrastructure and civil works, on board unit acquisition, advertising) or operational (enforcement, back office maintenance, infrastructure maintenance). Other costs like back office investment or on board unit maintenance are very small with respect to the total costs, so their effects can be considered as negligible.

+10%	**Total Costs**	**Benefits**	**B-C**	**10 years IRR**
Initial Situation	**3 825 300 €**	**3 993 600 €**	**168 300 €**	**4.4%**
Invesment Cost				
INFRASTRUCTURE (traffic lights) AND CIVIL WORKS	4 105 530 €	**3 993 600 €**	-111 930 €	**-2.7%**
ADVERTISING AND PUBLICITY	**3 827 300 €**	**3 993 600 €**	166 300 €	**4.3%**
Operational Cost				
BACK OFFICE MAINTENANCE	**3 825 700 €**	**3 993 600 €**	167 900 €	**4.4%**
INFRASTRUCTURE MAINTENANCE	3 923 700 €	**3 993 600 €**	69 900 €	**1.8%**
ON BOARD UNIT MAINTENANCE	**3 826 800 €**	**3 993 600 €**	166 800 €	**4.4%**

-10%	Total Costs	Benefits	B-C	10 years IRR
Initial Situation	**3 825 300 €**	**3 993 600 €**	**168 300 €**	**4.4%**
Invesment Cost				
INFRASTRUCTURE (traffic lights) AND CIVIL WORKS	**3 545 070 €**	**3 993 600 €**	448 530 €	**12.7%**
ADVERTISING AND PUBLICITY	**3 823 300 €**	**3 993 600 €**	170 300 €	**4.5%**
Operational Cost				
ON BOARD UNIT MAINTENANCE	**3 823 800 €**	**3 993 600 €**	169 800 **€**	**4.4%**
BACK OFFICE MAINTENANCE	3 824 900 €	**3 993 600 €**	168 700 €	**4.4%**
INFRASTRUCTURE MAINTENANCE	3 726 900 €	**3 993 600 €**	266 700 €	**7.2%**

In this case, the critical variable is the infrastructural cost, which includes both technological and civil works components.

6.2.5. Overall cost-benefit analysis

Hypotheses and assumptions

- *Individual (carriers) viewpoint*

First, it is important to quantify the benefits of EEIC for a transport company. In this case, we can identify four direct benefits for a carrier:

  - Fuel savings, directly translated into economic gains (money savings related to fuel consumption).

  - Time savings, also directly translated into economic gains (money savings related to timetabling and working hours).

  - CO_2 savings, which can be related to economic gains if a Carbon Tax is assumed.

Fuel savings can be estimated in a similar way for each scenario, since we can consider that all three scenarios will have similar impacts on drivers. However, there are some differences from one scenario to another. In all three cases, the distance savings will be estimated by calculating the fuel savings in g/km then by pondering by the number of km travelled by vehicles. Three main differences are then observed in the different scenarios:

1. The number of equipped traffic lights is similar, but with green waves they are more strategically positioned.

2. Cooperative systems need to take into account lacks of communication (mainly in intersections at the beginning and the end of EEIC corridors) which decrease the overall fuel savings.

3. S1 assumes the system is working between 9:00 and 11:30 a.m. and between 7:30 p.m. and 6:00 a.m. Moreover, since lanes are not specific there is a mixture of traffic and priorities, which is traduced into a less performing result. S2 supposes a higher level of performance since lanes are specific, with higher speeds then higher fuel savings. S3 estimations are extrapolated from S1 and S2, taking into account that on a

coordinated system there are no lacks of communication and when drivers are used to it, results can be close to but a little lower than those of S2.

The assumptions and reasons shown above are also applied to time savings and CO_2 savings, since the calculation is similar to fuel savings.

Indicator	S1	S2	S3
Travel speed (km/h)	+1,20	+4,00	+2,8
Travel time(s)	-3,33	-11,11	-6,78
Fuel consumption (g)	-1,67	-5,56	-3,75
CO2 emissions (g)	-48,33	-161,11	-87,23
NOx emissions (g)	-0,03	-0,11	-0,08

Table 32. Fuel and CO2 gaps for EEIC in a deployment situation (a negative value indicates a reduction, a positive value an increase)

We make the following assumptions:

1. The deployment of the EEIC allows an average usage of the system, per vehicle, of 25km, from the second year, since the equipped intersections are made in complete access paths. We consider that vehicles entering the system make routes that allow travelling the proposed distance as a part of their route.

2. Fuel savings are estimated in g, then converted into l using an average volumetric mass for fuel of 750 g/l. Moreover, a fuel cost of 1.3 €/l is assumed (this is the current value in France, according to CNR (2012), it can be updated to the current value for each country).

3. Concerning CO_2, we assume a carbon tax for each transport carrier. Although the current value is 17€/ton, we aim to set it to 100 €/ton, according to the last European Considerations (French Ministery of Land Use and Transport, 2005).

S1 analysis

- *Individual (carriers) viewpoint*

The benefit table for a transport carrier in the S1 is the following (results are related to each vehicle):

Type of gain	Stakeholder	Economic gain (€/year)
Vehicle usage	Transport operator	0 €/year (no distance gains)
Time savings	Transport operator	60 €/year
Fuel savings	Transport operator	20 €/year
CO_2 reduction	Transport operator	30 €/year
Total savings	Transport operator	110 €/year

In this case, since there are non-negligible investment, operational and maintenance costs, a 10-years classic CBA should be made. However, we observe that benefits are smaller than operational costs, so making it has no sense: the system, even with socio-economic costs, is not viable.

Type of cost	Type of cost	Economic costs
Onboard unit	Investment	500 €
Fee	Operational	400 €/year
Maintenance	Operational	250 €/year
Total investment costs		500 €
Total operational costs		650 €/year

- *Collective (Public authorities') viewpoint*

From the collective viewpoint, i.e. that of the public authority concerned by the implementation of the EEIC system, costs are those of the economic analysis made above (S2). To the chosen fee, other benefits can be defined, only related to CO_2 reductions:

- The most important benefit derives from CO_2 emission gains (NOx estimation is less accurate, so we prefer to not make hypotheses about this pollutant for precaution). To calculate this benefit, we apply the gains individuated for each transport carrier then we correct this result to take into account the fact that EEIC systems are active from 9:00 to 11:30 a.m. and from 7:30 p.m. to 6:00 a.m.

- Other benefits (congestion, fuel consumption, social benefits) are not considered since they are difficult to estimate and to consider on public authorities' viewpoint. Fuel consumption of FREILOT vehicles is difficult to be included in a collective analysis, as well as it is for congestion improvements. Moreover, time gains are difficult to be converted into quantitative benefits for public authorities, and security issues should need complementary data that has not been collected due to the difficulty to capture it (number of incidents, nature of incidents).

In the CBA, costs remain the same as that of the S2 configuration. Benefits change, since environmental impacts are traduced to economic values:

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
FEE by vehicle	315,00 €	315,00 €	315,00 €	315,00 €	315,00 €	315,00 €	315,00 €
Total FEE	0,00 €	63.000,00 €	157.500,00 €	252.000,00 €	346.500,00 €	409.500,00 €	409.500,00 €
CO2 gains-Freight	0,00 €	3.383,33 €	8.458,33 €	13.533,33 €	18.608,33 €	21.991,67 €	21.991,67 €
Total benefits	0,00 €	66.383,33 €	165.958,33 €	265.533,33 €	365.108,33 €	431.491,67 €	431.491,67 €
ROI	**-392.981,00 €**	**-578.286,27 €**	**-500.711,27 €**	**-279.943,87 €**	**25.419,73 €**	**309.591,67 €**	**309.591,67 €**
Balance of operational costs	**0,00 €**	**44.483,33 €**	**112.058,33 €**	**179.633,33 €**	**255.208,33 €**	**321.591,67 €**	**309.591,67 €**

We report the 10-years net present value trend (assuming a yearly updating rate of 4%) into the following graph:

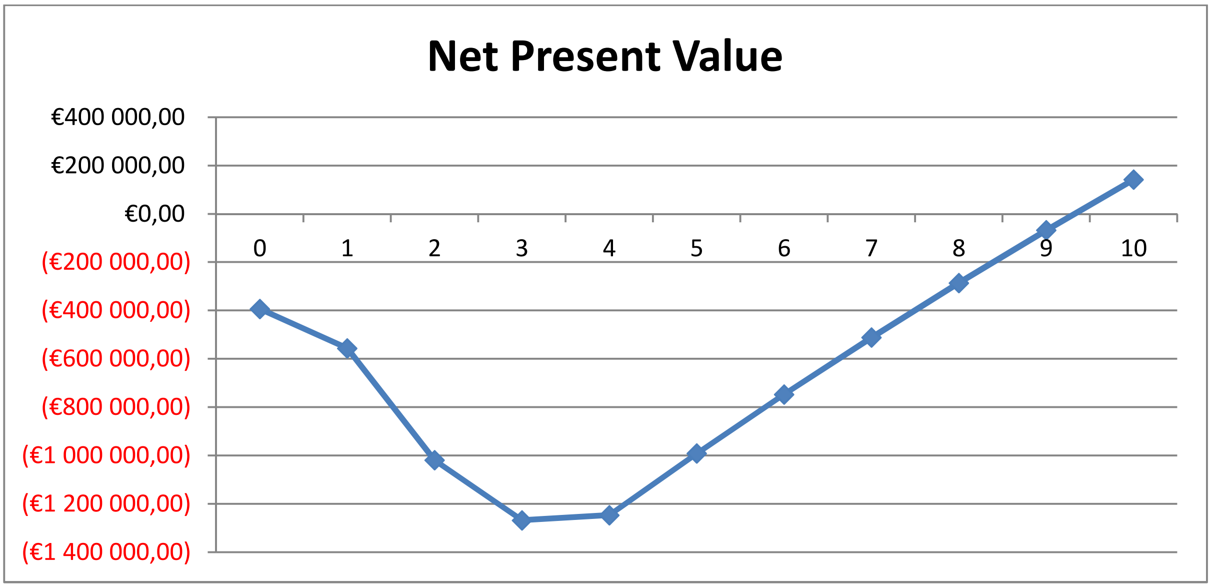

Figure 58. NPV evolution in a 10-years horizon with current settings and a yearly fee of 400 €/vehicle with VAT

The results confirm that the service can reach a balance after 10 years (IRR after 10 years: 4.3%) with a fee reduction (the new fee is about 380 €/year). However, we observe that investment costs are more important in this case that in DSB services, which means that operationally, the system is still rentable at year 1, and after all investments are made, the benefits allow to quickly increase the NPV.

If we return to the carrier's viewpoint, the fee reduction of 20 €/year and vehicle can be considered as negligible.

S2 analysis

- *Individual (carriers) viewpoint*

The benefit table for a transport carrier in the S1 is the following (results are related to each vehicle):

Type of gain	Stakeholder	Economic gain (€/year)
Vehicle usage	Transport operator	0 €/year (no distance gains)
Time savings	Transport operator	190 €/year
Fuel savings	Transport operator	60 €/year
CO_2 reduction	Transport operator	100 €/year
Total savings	Transport operator	350 €/year

In this case, since there are non-negligible investment, operational and maintenance costs, a 10-years classic CBA should be made. However, we observe that benefits are still smaller than operational costs, so making it has no sense: the system, even with socio-economic costs, is not viable.

Type of cost	Type of cost	Economic costs
Onboard unit	Investment	5000 €
Fee	Operational	400 €/year
Maintenance	Operational	350 €/year
Total investment costs		5000 €
Total operational costs		750 €/year

- *Collective (Public authorities') viewpoint*

From the collective viewpoint, i.e. that of the public authority concerned by the implementation of the EEIC system, costs are those of the economic analysis made above (S2). To the chosen fee, other benefits can be defined, only related to CO_2 reductions:

- The most important benefit derives from CO_2 emission gains (NOx estimation is less accurate, so we prefer to not make hypotheses about this pollutant for precaution). To calculate this benefit, we apply the gains individuated for each transport carrier and we aggregate the results taking into account that in reserved lanes are available 24h per day.

- Other benefits (congestion, fuel consumption, social benefits) are not considered since they are difficult to estimate and to consider on public authorities' viewpoint. Fuel consumption of FREILOT vehicles is difficult to be included in a collective analysis, as well as it is for congestion improvements. Moreover, time gains are difficult to be converted into quantitative benefits for public authorities, and security issues should need complementary data that has not been collected due to the difficulty to capture it (number of incidents, nature of incidents).

In the CBA, costs remain the same as that of the S2 configuration. Benefits change, since environmental impacts are traduced to economic values:

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
FEE by vehicle	325,00 €	325,00 €	325,00 €	325,00 €	325,00 €	325,00 €	325,00 €
Total FEE	0,00 €	65.000,00 €	162.500,00 €	260.000,00 €	357.500,00 €	422.500,00 €	422.500,00 €
CO2 gains-Freight	0,00 €	11.277,78 €	28.194,44 €	45.111,11 €	62.027,78 €	73.305,56 €	73.305,56 €
Total benefits	0,00 €	76.277,78 €	190.694,44 €	305.111,11 €	419.527,78 €	495.805,56 €	495.805,56 €
ROI	**-477.050,00 €**	**-702.902,22 €**	**-610.485,56 €**	**-341.248,89 €**	**29.397,78 €**	**373.905,56 €**	**373.905,56 €**
Balance of operational costs	**0,00 €**	**54.377,78 €**	**136.794,44 €**	**219.211,11 €**	**309.627,78 €**	**385.905,56 €**	**373.905,56 €**

We report the 10-years net present value trend (assuming a yearly updating rate of 4%) into the following graph:

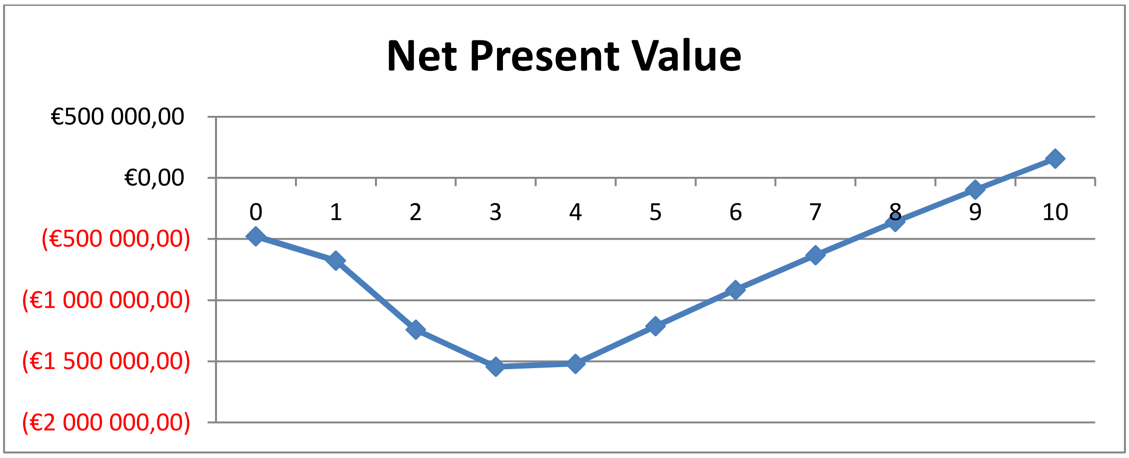

Figure 59. NPV evolution in a 10-years horizon with current settings and a yearly fee of 390 €/vehicle with VAT

The fee can be reduced to 390 € per vehicle and year, due to the benefits which are higher in reserved lanes, we can assume that freight vehicles can travel all day without a limitation on the number of hours), which is traduced by a monthly fee of 32,50 € per vehicle.

S3 analysis

The benefit table for a transport carrier in the S1 is the following (results are related to each vehicle):

Type of gain	Stakeholder	Economic gain (€/year)
Vehicle usage	Transport operator	0 €/year (no distance gains)
Time savings	Transport operator	125 €/year
Fuel savings	Transport operator	45 €/year
CO_2 reduction	Transport operator	55 €/year
Total savings	Transport operator	225 €/year

In this case, since there are no costs for operators, there is a clear gain of using the system and changing some paths to use green wave lines in order to benefit of those environmental and social benefits.

- *Collective (Public authorities') viewpoint*

From the collective viewpoint, i.e. that of the public authority concerned by the implementation of the EEIC system, costs are those of the economic analysis made above (S2). To the chosen fee, other benefits can be defined, only related to CO_2 reductions:

- The most important benefit derives from CO_2 emission gains (NOx estimation is less accurate, so we prefer to not make hypotheses about this pollutant for precaution). To calculate this benefit, we apply the gains individuated for each transport carrier and we aggregate the results taking into account that in reserved lanes are available 24h per day.

- Other benefits (congestion, fuel consumption, social benefits) are not considered since they are difficult to estimate and to consider on public authorities' viewpoint. Fuel consumption of FREILOT vehicles is difficult to be included in a collective analysis, as well as it is for congestion improvements. Moreover, time gains are difficult to be converted into quantitative benefits for public authorities, and security issues should need complementary data that has not been collected due to the difficulty to capture it (number of incidents, nature of incidents).

In the CBA, costs remain the same as that of the S3 configuration. Benefits change, since environmental impacts are traduced to economic values. :

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
Number of Vehicles	0	200	500	800	1100	1300	1300
Total FEE	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
CO2 gains-Freight	0,00 €	10.685,68 €	26.714,19 €	42.742,70 €	58.771,21 €	69.456,89 €	69.456,89 €
Total benefits	0,00 €	10.685,68 €	26.714,19 €	42.742,70 €	58.771,21 €	69.456,89 €	69.456,89 €
ROI	**-147.132,56 €**	**-221.226,43 €**	**-199.197,91 €**	**-132.316,38 €**	**-37.008,33 €**	**54.456,89 €**	**54.456,89 €**
Balance of operational costs	**0,00 €**	**8.185,68 €**	**20.214,19 €**	**32.242,70 €**	**45.271,21 €**	**55.956,89 €**	**54.456,89 €**

We report the 10-years net present value trend (assuming a yearly updating rate of 4%) into the following graph:

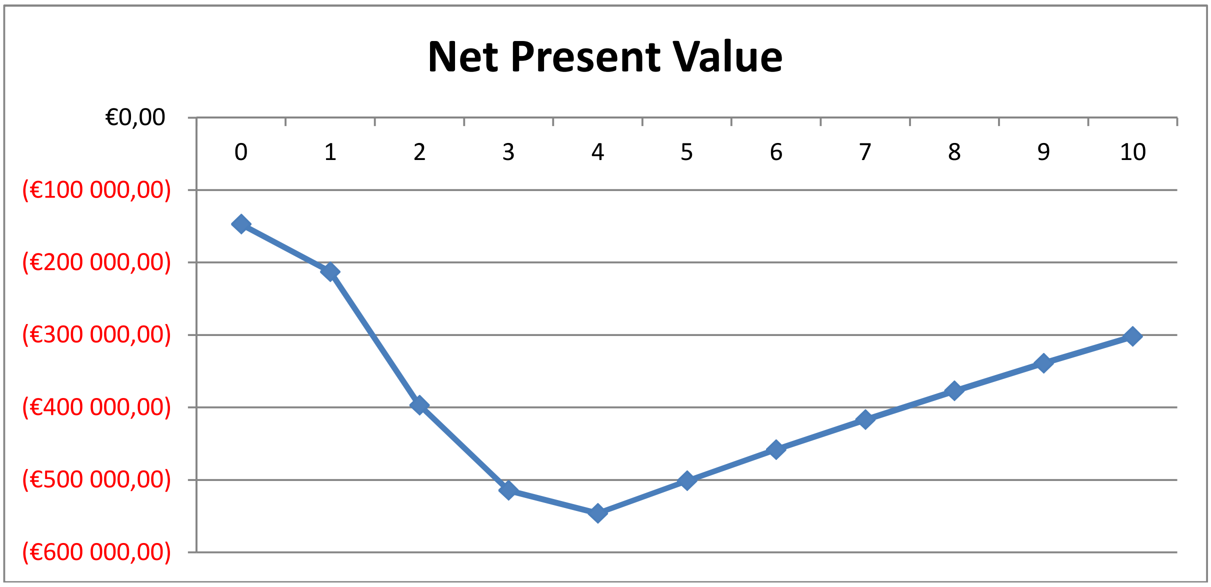

Figure 60. NPV evolution in a 10-years horizon with current settings but no fee (green wave)

The NPV increases after year 4 although that increase is not enough to compensate the investments. However, a green wave does not need to ask for a fee, so if we consider the service accessible to everybody, the number of trucks using it will increase. Considering that 4000 vehicles remains still a good number taking into account the characteristics of urban goods movement, we propose a second hypothesis of green wave usage:

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
Number of Vehicles	0	500	1500	2500	4000	4000	4000
Total FEE	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
CO2 gains-Freight	0,00 €	26.714,19 €	80.142,56 €	133.570,94 €	213.713,50 €	213.713,50 €	213.713,50 €
Total benefits	0,00 €	26.714,19 €	80.142,56 €	133.570,94 €	213.713,50 €	213.713,50 €	213.713,50 €
ROI	**-147.132,56 €**	**-205.197,91 €**	**-145.769,54 €**	**-41.488,14 €**	**117.933,96 €**	**198.713,50 €**	**198.713,50 €**
Balance of operational costs	**0,00 €**	**24.214,19 €**	**73.642,56 €**	**123.070,94 €**	**200.213,50 €**	**200.213,50 €**	**198.713,50 €**

The CBA is then more interesting, since an IRR of more than 50% appears to become with this configuration:

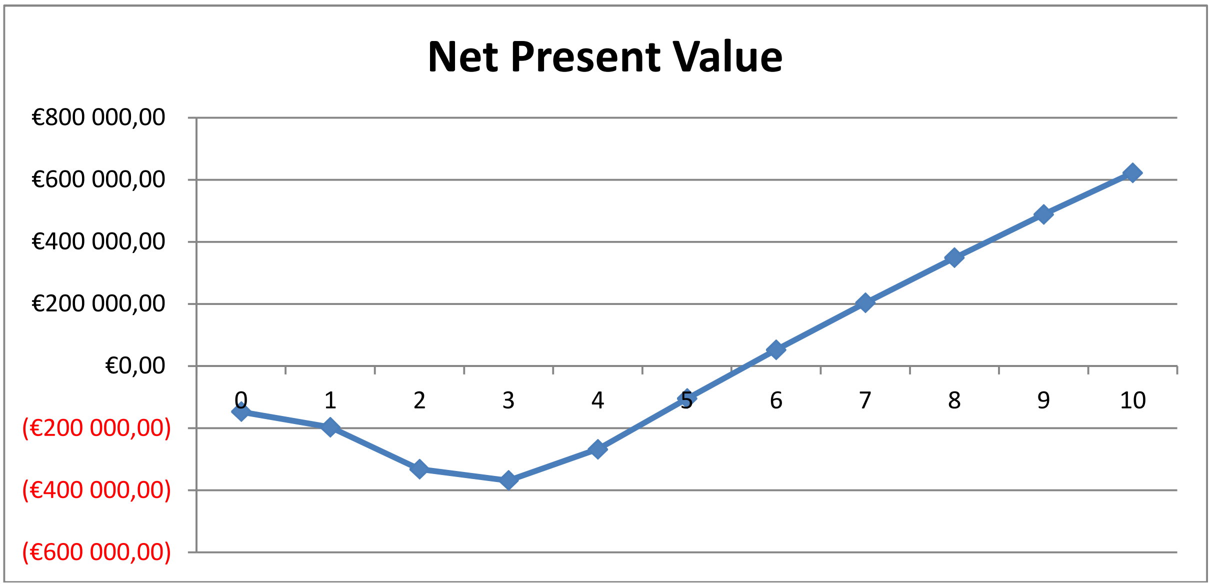

Figure 61. NPV evolution in a 10-years horizon with 4000 vehicles using the green wave after year 4.

Looking at those NPV trends, the green wave seems to be the most suitable system, for both cost and acceptability reasons.

6.2.6. Application to other cities

For EEIC, an analysis by size of city in terms of number of inhabitants is possible. Indeed, we can relate the quantity and quality of access infrastructures to the city size. In other words, the number and characteristics of access roads will be similar for cities of the same category. As seen in the following table, we obtain non-evident results: for small and very big cities, the EEIC systems are very interesting, with 10-years IRRs of over 15%. This is explained by the fact that in small cities only a few intersections need to be equipped, since most of the accesses to the various city areas are covered by a set of 3 to 5 axes. In big cities, a higher investment is needed (about 20-25 axes), but the number of involved vehicles is higher, and the space can be sectored, allowing vehicles to profit the benefits of taking reserved axes.

	Number of intersections	**Number of vehicles**	**Fee**	**IRR**
100 000 to 500 000 inhab	50	500	300 €	15,20%
500 000 to 1 million inhab	100	900	300 €	6,20%
1 to 5 million inhab	150	1300	300 €	2,10%
5 to 10 million inhab	250	2000	300 €	17,70%

Table 33. IRR for different categories of cities

For medium urban areas, the results are more mitigated, but remain still interesting for cities up to 1 million inhabitants. In order to increase IRRs for cities of 1 to 5 million inhabitants, it is important to target a larger number of trucks, in order to increase the number of systems, or to increase the fee, but this second solution would lead to a decrease of the number of vehicles using the system.

6.3. *In-vehicle systems*

6.3.1. Pilot characteristics and evaluation conclusion recalls

As shown in D.FL. 4.1 (Evaluation methodology) and D.FL. 4.2 (Evaluation results)he in-vehicle systems evaluation has been heterogeneous and presented different test cases with a small number of vehicles each. Moreover, all cities have been covered. The main results of the evaluation are synthesised in below. Note that the interest of in-vehicle systems for the city are seen for vehicles circulating in city centres so the evaluation results have been aggregated to estimate the effects of in-vehicle systems in such situations.

Indicator	AL/SL gains	EDS gains	
		Optimistic	Conservative
Fuel consumption (g/km)	0%	3.6%	1.8%
CO2 emissions (g/km)	0%	3.6%	1.8%

Table 34. Gains of using in-vehicle systems. Results extrapolated from evaluation conclusions

6.3.2. Scenario characteristics and hypotheses

In the Cost Benefit Analysis, two possibilities are tested:

- S1: EDS device.
- S2: AL/SL device.

To set the scenarios on the same basis in order to allow a comparison between them, each scenario will be defined on a hypothetic city, in which we assume a progressive development of the system to have 1300 vehicles with in-vehicle systems. The deployment assumptions are the following:

Year 1: 1 city, 200 vehicles.
Year 2: 1 city, 300 vehicles.
Year 3: 1 city, 300 vehicles.
Year 4: 1 city, 300 vehicles.
Year 5: 1 city, 200 vehicles.
TOTAL: 1 city, 1300 vehicles.

Moreover, no infrastructural investments are required from the cities.

6.3.3. Cost-benefit analysis

First, an only economic cost-benefit analysis is made. In all three situations, two estimations are made. A 10-years forecasting analysis is made, first with basic hypotheses defined by the vehicle manufacturer (Volvo) then a second analysis is made changing the various service settings to find the best service configuration to result on a rentable system.

S1 analysis

In this scenario we focus on vehicle manufacturer’s viewpoint. The main hypotheses are the following:

Investment costs:

- Back office: No back office investment costs are supposed, since this system can be assimilated to other telematics options of a vehicle.
- Infrastructure and civil works: Not applied.
- On board unit investment: a commercial solution is supposed, and it is supposed to be paid by the transport carrier. Since the system is not commercial, an investment cost for developing it is assumed.
- On board unit production: each unit has a unitary cost that is taken into account.

Operational costs

- Back office: we suppose back office functional costs are assimilated to other telematics services and can be considered as negligible.
- Enforcement: Not applied.
- On board unit: costs estimated by vehicle manufacturer (Volvo) per vehicle, assumed by the transport carriers.

The hypotheses concerning the deployment of in-vehicle systems are the following:

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6+**
Number of units	**0**	**200**	**500**	**800**	**1100**	**1300**	**1300**

In the following table we can see the costs and direct benefits for the vehicle manufacturer:

Volvo – INVESTMENT COSTS							
	AFFECTED ACTOR	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
BACK OFFICE – INITIAL INVESTMENT	Manufacturer	500 000,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ON BOARD UNIT INVESTMENT	Manufacturer	4 500 000,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ON BOARD UNIT PRODUCTION	Manufacturer	0,00 €	40 000,00 €	60 000,00 €	60 000,00 €	60 000,00 €	40 000,00 €
TOTAL		5 000 000,00 €	40 000,00 €	60 000,00 €	60 000,00 €	60 000,00 €	40 000,00 €

Volvo – OPERATIONAL COSTS							
	AFFECTED ACTOR	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
BACK OFFICE FUNCTIONAL COSTS	Manufacturer	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ENFORCEMENT	Manufacturer	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
BACK OFFICE MAINTENANCE	Manufacturer	0,00 €	20 000,00 €	30 000,00 €	30 000,00 €	30 000,00 €	20 000,00 €
TOTAL		0,00 €	20 000,00 €	30 000,00 €	30 000,00 €	30 000,00 €	20 000,00 €

As for DSB and EEIC, the first analysis seeks to find the minimum income the system needs to be economically viable. In this case, two incomes are defined: a yearly fee of 240 € (with VAT) per vehicle (to ensure the service) and a technological price of 3 500 000 € (without VAT) for commercialising the system.

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Over year 6**
Number of Vehicles	0	200	500	800	1100	1300	1300
Investment COST	5 000 000,00 €	40 000,00 €	60 000,00 €	60 000,00 €	60 000,00 €	40 000,00 €	40 000,00 €
Operational COST	0,00 €	20 000,00 €	30 000,00 €	30 000,00 €	30 000,00 €	20 000,00 €	20 000,00 €
Total COST	5 000 000,00 €	60 000,00 €	90 000,00 €	90 000,00 €	90 000,00 €	60 000,00 €	60 000,00 €
Investment COST by vehicle	n.a.	25 000,00 €	80,00 €	75,00 €	54,55 €	46,15 €	30,77 €
Operational COST by vehicle	n.a.	100,00 €	60,00 €	37,50 €	27,27 €	15,38 €	15,38 €
Total COST by vehicle	**n.a.**	**25 100,00 €**	**140,00 €**	**112,50 €**	**81,82 €**	**61,54 €**	**46,15 €**
Price of the system	**3 500,00 €**	**3 500,00 €**	**3 500,00 €**	**3 500,00 €**	**3 500,00 €**	**3 500,00 €**	**3 500,00 €**
FEE by vehicle	**200,00 €**	**200,00 €**	**200,00 €**	**200,00 €**	**200,00 €**	**200,00 €**	**200,00 €**
Total FEE	**0,00 €**	**740 000,00 €**	**1 150 000,00 €**	**1 210 000,00 €**	**1 270 000,00 €**	**960 000,00 €**	**260 000,00 €**
Balance of cumulated total costs	**-5 000 000,00 €**	**-4 280 000,00 €**	**-3 200 000,00 €**	**-2 080 000,00 €**	**-900 000,00 €**	**-20 000,00 €**	**180 000,00 €**
Balance of operational costs (for each year)	**0,00 €**	**720 000,00 €**	**1 120 000,00 €**	**1 180 000,00 €**	**1 240 000,00 €**	**940 000,00 €**	**240 000,00 €**

We report the 10-years net present value trend (assuming a yearly updating rate of 4%) into the following graph:

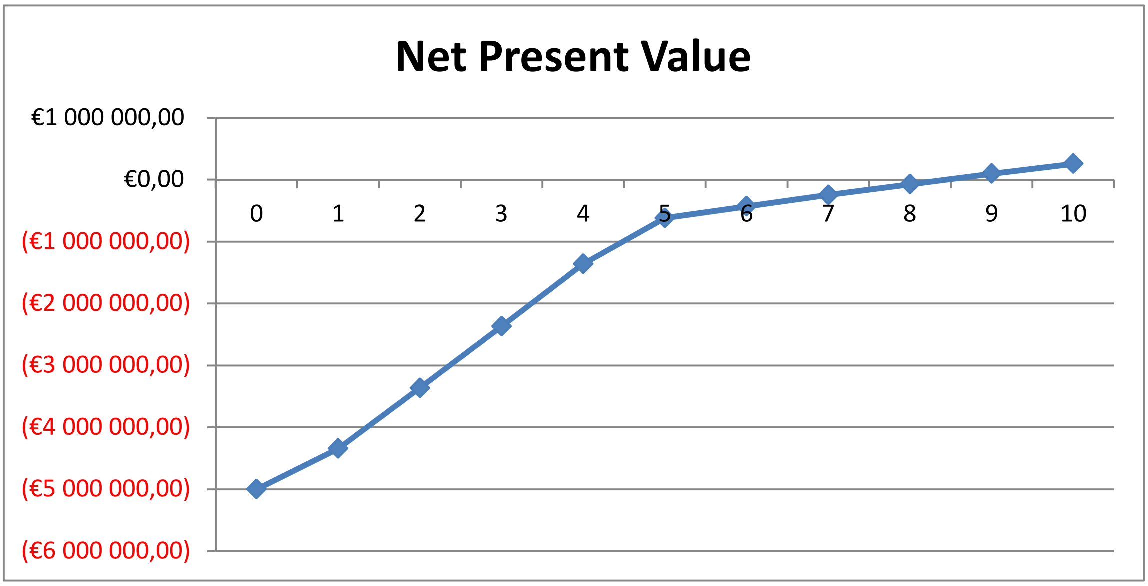

Figure 62. NPV evolution in a 10-years horizon with current settings

The difference with respect to other systems arises on the initial investment of the system, which is very big, but is balanced by the introduction of equipped vehicles. In the current configuration, vehicles are equipped the first 5 years, but we should introduce more vehicles even in the other 5 years.

<u>S2 analysis</u>

In this situation we consider the AL/SL system. In the following table we can see the costs and direct benefits for the automotive manufacturer:

Volvo – INVESTMENT COSTS

	AFFECTED ACTOR	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
BACK OFFICE – INITIAL INVESTMENT	Manufacturer	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ON BOARD UNIT INVESTMENT	Manufacturer	5 000 000,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ON BOARD UNIT PRODUCTION	Manufacturer	0,00 €	300 000,00 €	450 000,00 €	450 000,00 €	450 000,00 €	300 000,00 €
ADVERTISING AND PUBLICITY	City	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
TOTAL		5 000 000,00 €	300 000,00 €	450 000,00 €	450 000,00 €	450 000,00 €	300 000,00 €

Volvo – OPERATIONAL COSTS

	AFFECTED ACTOR	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
BACK OFFICE FUNCTIONAL COSTS	Manufacturer	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
ENFORCEMENT	Manufacturer	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
BACK OFFICE MAINTENANCE	Manufacturer	0,00 €	30 000,00 €	45 000,00 €	45 000,00 €	45 000,00 €	30 000,00 €
TOTAL		0,00 €	30 000,00 €	45 000,00 €	45 000,00 €	45 000,00 €	30 000,00 €

As for S1, the first analysis seeks to find the minimum incomes the system needs to be economically rentable. In this case, the prices are higher to those of EDS: a yearly fee of 360 € (with VAT) per vehicle (to ensure the service) and a technological price of 4 200 000 € (without VAT).

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Over year 6
Number of Vehicles	0	200	500	800	1100	1300	1300
Investment COST	5 000 000,00 €	300 000,00 €	450 000,00 €	450 000,00 €	450 000,00 €	300 000,00 €	300 000,00 €
Operational COST	0,00 €	30 000,00 €	45 000,00 €	45 000,00 €	45 000,00 €	30 000,00 €	30 000,00 €
Total COST	5 000 000,00 €	330 000,00 €	495 000,00 €	495 000,00 €	495 000,00 €	330 000,00 €	330 000,00 €
Investment COST by vehicle	n.a.	25 000,00 €	600,00 €	562,50 €	409,09 €	346,15 €	230,77 €
Operational COST by vehicle	n.a.	150,00 €	90,00 €	56,25 €	40,91 €	23,08 €	23,08 €
Total COST by vehicle	**n.a.**	**25 150,00 €**	**690,00 €**	**618,75 €**	**450,00 €**	**369,23 €**	**253,85 €**
Price of the system	4 200,00 €	4 200,00 €	4 200,00 €	4 200,00 €	4 200,00 €	4 200,00 €	4 200,00 €
FEE by vehicle (without VAT)	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €
Total FEE	0,00 €	900 000,00 €	1 410 000,00 €	1 500 000,00 €	1 590 000,00 €	1 230 000,00 €	390 000,00 €
Balance of cumulated total costs	**-5 000 000,00 €**	**-4 130 000,00 €**	**-3 065 000,00 €**	**-2 060 000,00 €**	**-965 000,00 €**	**-215 000,00 €**	**-155 000,00 €**
Balance of operational costs (for each year)	**-5 000 000,00 €**	**870 000,00 €**	**1 365 000,00 €**	**1 455 000,00 €**	**1 545 000,00 €**	**1 200 000,00 €**	**360 000,00 €**

We report the 10-years net present value trend (assuming a yearly updating rate of 4%) into the following graph:

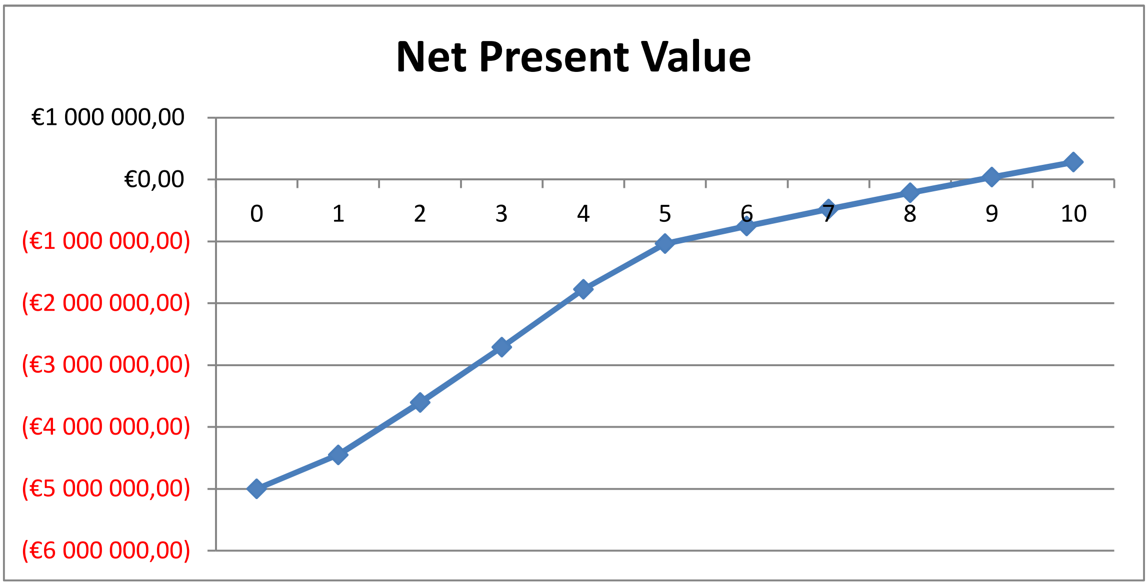

Figure 63. NPV evolution in a 10-years horizon with current settings

The results are very close to those of S1, but the needed incomes are higher.

6.3.4. Sensitivity analysis

Once a suitable scenario is selected (in this case, S2 with best configurations) it is important to test the sensitivity of the different variables. For this reason, we make a second simulation changing the values of each group of variables. We assume a margin of 10% in cost estimations, i.e. we consider that each group of costs is increased or decreased by 10%, either investment (infrastructure and civil works, on board unit acquisition, advertising) or operational (enforcement, back office maintenance, infrastructure maintenance). Other costs like back office investment or on board unit maintenance are very small with respect to the total costs, so their effects can be considered as negligible.

+10%	**Total Costs**	**Benefits**	**B-C**	**10 years IRR**
Initial Situation	**5 490 000 €**	**6 630 000 €**	**256 132 €**	**4.7%**
Invesment Cost				
BACK-OFFICE INITIAL INVESTMENT	**5 540 000 €**	**6 630 000 €**	206 132€	**3.7%**
ON BOARD UNIT INVESTMENT	**5 940 000 €**	**6 630 000 €**	-193 867 €	**-3.3%**
ON BOARD UNIT PRODUCTION	5 516 000 €	**6 630 000 €**	232 988 €	**4.2%**
Operational Cost				
BACK OFFICE MAINTENANCE	5 513 000 €	**6 630 000 €**	237 242 €	**4.3%**

-10%	**Total Costs**	**Benefits**	**B-C**	**10 years IRR**
Initial Situation	**5 490 000 €**	**6 630 000 €**	**256 132 €**	**4.7%**
Invesment Cost				
BACK-OFFICE INITIAL INVESTMENT	**5 440 000 €**	**6 630 000 €**	**306 132 €**	**5.6%**
ON BOARD UNIT INVESTMENT	**5 040 000 €**	**6 630 000 €**	**706 132 €**	**14%**
ON BOARD UNIT PRODUCTION	5 464 000 €	**6 630 000 €**	279 276 €	**5.1%**
Operational Cost				
BACK OFFICE MAINTENANCE	5 467 000 €	**6 630 000 €**	275 022 €	**5%**

The most sensible variable is on board unit investment. However, this variable can be related to the total estimated number of sold units (not communicated by the manufacturer), to its sensitivity can decrease.

6.3.5. Application to other cities

In-vehicle systems are not specifically conceived for urban context, since they have been conceived and designed to be implemented on long haul trucks, and urban vehicles are in general small and medium trucks (mainly 3.5T, 9T. or 12 to 19T.). Although the acceleration and speed limiters (AL and SL) could be applied to urban context, their maturity has not been reached and the small (even negligible benefits) implies an almost zero impact in practice. Moreover, the calibration of limitation zones depends strongly on the city physical characteristics and its involvement (surface of the area, number of zones). Furthermore, the conclusions of the evaluation do not give enough elements to transpose such results to other cities (see deliverable D.FL. 4.2 Evaluation Results), so a further evaluation should be needed to make a correct transposition and transferability framework to different cities. For that reason, and showing the negligible impact of the system for a relatively big city, the analysis on cities of other sizes is difficult to make for AL and SL. In any case, if we quickly transpose such elements to a small city (less than 500 000 inhabitants), the results of the CBA are quite similar. The case of big cities is more critical, since a big number of zones are needed and it is needed to ensure the correct utilization of the system, which consequences are unfortunately not clear from the evaluation results.

Inhabitants	**Total nbr of km**	**Nbr of vehicles**	**System manager's IRR**	**Individual benefits (per vehicle and year)**
Less than 100 000	150	1300	2.20%	53 €
100 to 500 000	100	1300	2.20%	Negligible
500 000 to 1 million	60	1300	2.20%	Negative
1 to 3 million	75	1300	2.20%	Negligible

Table 35. Application of AL to different cities

Concerning EDS, the system can have different impacts with respect to the city size (in inhabitants) as shown in the following table:

Inhabitants	**Total nbr of km**	**Nbr of vehicles**	**System manager's IRR**	**Individual benefits (per vehicle and year)**
Less than 100 000	150	1300	4.70%	585 €
100 to 500 000	100	1300	4.70%	390 €
500 000 to 1 million	60	1300	4.70%	210 €

1 to 3 million	75	1300	4.70%	260 €

Table 36. Application of EDS to different cities

The two first categories of cities are small, that have to be considered on the logic of regional or national distribution schemes. In this case, the urban parts are not concentrated by spread on a multipolar network. However, since the network logic is followed, the system has its best performance, allowing to earn about 590 € per vehicle and year. This confirms the scope of the system, which has to be inserted on at least regional routes (the benefits for urban medium and large areas are more mitigated because of the urban specificity of the context. In any case, the simulations are made with the same CBA method and the same number of systems and vehicles, which leads to the same IRR. However, in the two first cases we can assume that the stakeholder is regional or departmental, and in the other two it is urban.

6.1. Combined scenarios

Since EEIC and DSB are complementary and difficult to integrate at infrastructural or on board unit levels, we can assume that both costs and benefits can be obtained by addition. Concerning in-vehicle systems, a synergy with EEIC can be found for on-board units (manly for GPS devices) which can make the EEIC costs decrease, mainly for on-board investment. However, the overall benefits are difficult to be estimated since no joint evaluation results have been significant. Concerning DSB and in-vehicle systems, no interactions or synergies can be found between them, so costs and benefits can be also obtained by addition.

6.2. Conclusions of the CBA

The CBA shows how and under which conditions each system can work and be justified by both public authorities and transport carriers. DSB can be useful in central congested areas, but they need to constitute a network to make an important benefit to transport carriers (mainly due to time gains) and the urban collectives (mainly for CO2 emission gains due to traffic improvements. Cooperative EEIC systems seem useful if combining them with reserved lines, but are expensive for transport carriers. More interesting are green waves, which benefits can be obtained by trucks and some cars without individual costs, and small collective costs. In-vehicle systems gains are small, and their evaluation seems to be improved before concluding.

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