FREILOT. Urban Freight Energy Efficiency Pilot. D.FL.6.4. Cost-benefit analysis

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D.FL.6.4 Cost-Benefit Analysis

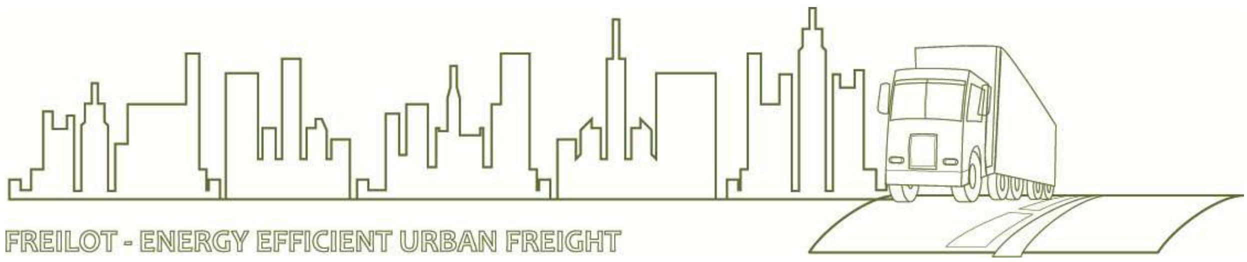

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Table of Contents

TABLE OF CONTENTS 5

ABBREVIATIONS AND DEFINITIONS 7

EXECUTIVE SUMMARY 8

1. INTRODUCTION 9

2. METHOD AND HYPOTHESES 10

2.1. GENERAL NOTIONS OF A COST-BENEFIT ANALYSIS METHODOLOGY 11

2.2. MAIN HYPOTHESES AND ASSUMPTIONS 11

3. RESULTS – ONE SYSTEM SCENARIOS 13

3.1. DELIVERY SPACE BOOKING 13

3.1.1. Pilot characteristics and evaluation conclusion recalls 13

3.1.2. Scenario characteristics and hypotheses 14

3.1.3. Economic viability analysis 14

3.1.4. Sensitivity analysis 23

3.1.5. Overall cost-benefit analysis 24

3.1.6. Application to different cities 26

3.2. ENERGY EFFICIENT INTERSECTION CONTROL 28

3.2.1. Pilot characteristics and evaluation conclusion recalls 28

3.2.2. Scenario characteristics and hypotheses 28

3.2.3. Economic viability analysis 29

3.2.4. Sensitivity analysis 34

3.2.5. Overall cost-benefit analysis 35

3.2.6. Application to other cities 41

3.3. IN-VEHICLE SYSTEMS 42

3.3.1. Pilot characteristics and evaluation conclusion recalls 42

3.3.2. Scenario characteristics and hypotheses 42

3.3.3. Cost-benefit analysis 42

3.3.4. Sensitivity analysis 46

3.3.5. Application to other cities 47

4. GENERAL CONCLUSIONS 48

4.1. COMBINED SCENARIOS 48

5. BIBLIOGRAPHY 49

6. TABLE OF FIGURES 50

7. TABLES 51

Abbreviations and Definitions

Abbreviation	Definition
ARTEMIS	A Semantic Web Service-Based P2P Infrastructure for the Interoperability of Medical Information System
BUA	Business as usual
CMEM	Comprehensive Modal Emissions Model
CO	Carbon monoxide
CO_2	Carbon dioxide
D.FL.	Deliverable Freilot
DAS	Data Recording System
DSB	Delivery Space Booking
EEIC	Energy Efficient Intersection Control
FTP	File Transfer Protocol
GIS	Geographic Information System
GPRS	General Packet Radio Service
GPS	Global Positioning System
HC	Hydrocarbon
HGV	Heavy Goods Vehicles
HMI	Human Machine Interface
IRR	Internal Rate of Return
LTL	Less Than Truckload
NO_x	Nitrogen Oxides
NPV	Net Present Value
Q	Quartile
RFID	Radio Frequency IDentification
RSU	Road Side Unit
TLC	Traffic Light Controller
UMDM	Urban Merchandising Distribution Management

Executive Summary

This deliverable contains the cost-benefit analysis results (CBA) for the piloted services in order to feed the Business Model discussions. First, a brief description of the method and the main hypotheses are shown. Then, each single system is presented, making several CBA analyses (corresponding to hypothesised scenarios). The best scenario for each system is chosen in terms of economic viability then a socio-economic CBA is carried out. Finally, a discussion about mixing systems is provided.

What can be concluded from the analysis is that for the Delivery Space Booking system the scenario 2 (hybrid parking machines) is the most economically viable. The fleet operators would in this case need to pay a yearly fee of 300 € to provide a net Investment Return Rate of 9.2 % over 10 years. For Energy Efficient Intersection Control the solution providing the best cost/benefit ratio is the third “green wave” alternative, although it need to be entirely financed by public funds, its costs are very small and the collective benefits are higher due to the free usage of it, by both private cars and commercial vehicles. For in-vehicle systems, simulations show that the impacts are in all cases negligible. We observe haowever an interest to use EDS, although a best effort on measuring its impacts needs to be done to conclude.

1. Introduction

Urban goods transport is a necessary but disturbing activity. To deal with the main nuisances related to it (mainly congestion, noise, global warming and local pollution), public and private stakeholders have studied and developed methods and solutions of different nature and dimensions (Gonzalez-Feliu, 2008). We observe in transport research hundreds of works dealing with the subject of commercial and goods transport, but the number of operational urban logistics systems is very small (Gonzalez-Feliu and Morana, 2010). Although a few projects have resulted on operational solutions nowadays implemented or in mature solutions able to be deployed, most of them remained at a project, experimental or limited scope status (Gonzalez-Feliu et al., 2013). The main limits of such projects arise on the difficulties of make a prospective deployment analysis and to define its suitable business models. Those difficulties are increased in technological-based projects, since real costs can even double the expected forecasting values, mainly due to dysfunctions and incompatibilities (Gonzalez-Feliu and Morana, 2011)

One of the main validation methods for business models or prospective analysis is that of cost-benefit analysis. In the FREILOT project, the various test cases are simulated and assessed in order to examine the robustness and validity of its business model. To do this, a double analysis is made. First, the main barriers and enablers to its development are identified. Second, a cost-benefit analysis is made to validate (or review) the proposed business models. This deliverable presents this second method.

The deliverable is organised as follows. First the method is proposed, making a quick overview of the CBA methodology and setting the main general hypotheses for the scenario simulation and assessment in terms of cost and benefit estimation. Second, each system is examined, making several CBA assessment analyses for single system cases. In those analyses, the identification of robust cost-benefit balance mechanism is a priority, after that, a sensitivity analysis and a simulation of different configurations (corresponding to different types of cities) are made. Fourth, a note on the application to combinations of systems is proposed. Finally, a general conclusion is provided to state on the suitability of deploying FREILOT systems.

2. Method and hypotheses

Cost-benefit analysis 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 region (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).

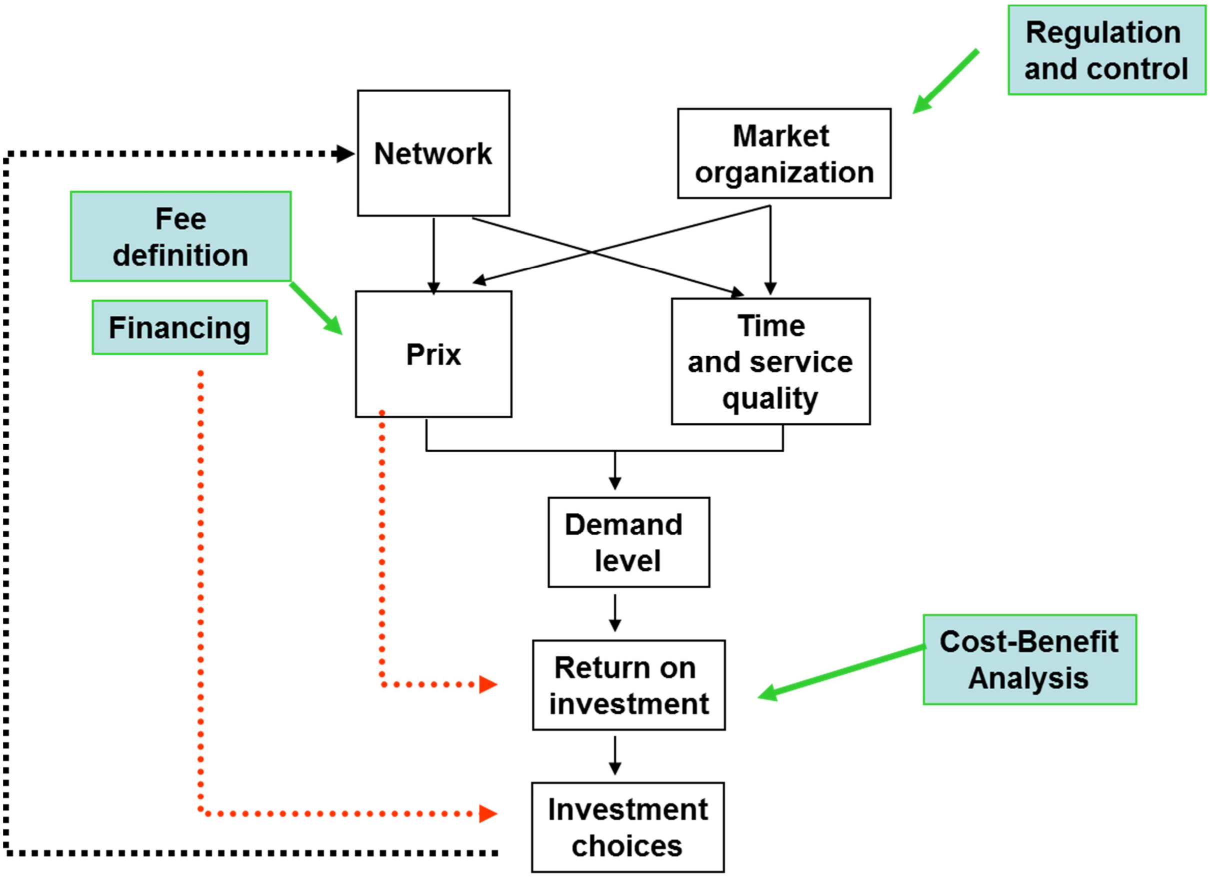

Figure 1: Position of Cost-Benefit Analysis (CBA) on the transport market command mechanisms (Source: Bruno Faivre d'Arcier and Alain Bonnafous, Laboratoire d'Economie des Transports)

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).

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).

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).

3. Results – one system scenarios

3.1. Delivery Space Booking

3.1.1. 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 1. 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[1] (the loss is due to the security and the tranquillity drivers feel when legally parking their vehicle with respect to double line parking 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.

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

3.1.2.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.

3.1.3.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[2].

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

- 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 €

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:

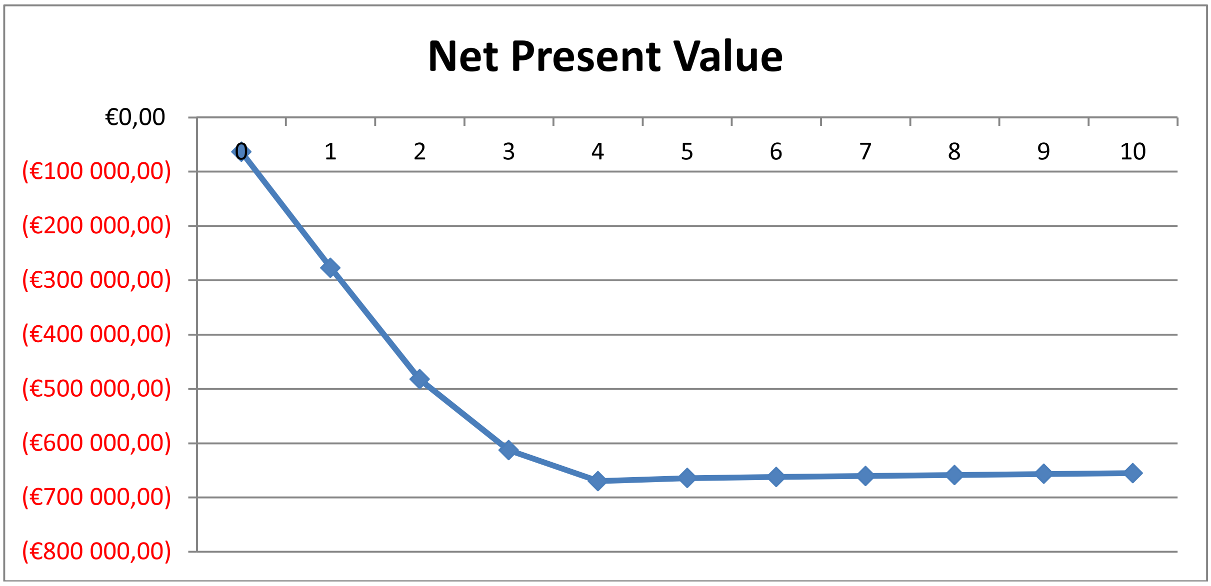

Figure 2. Net Present Value (NPV) evolution in a 10-years horizon with current settings and a yearly fee of 400 €/vehicle without VAT (i.e. 480€ with VAT)

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.

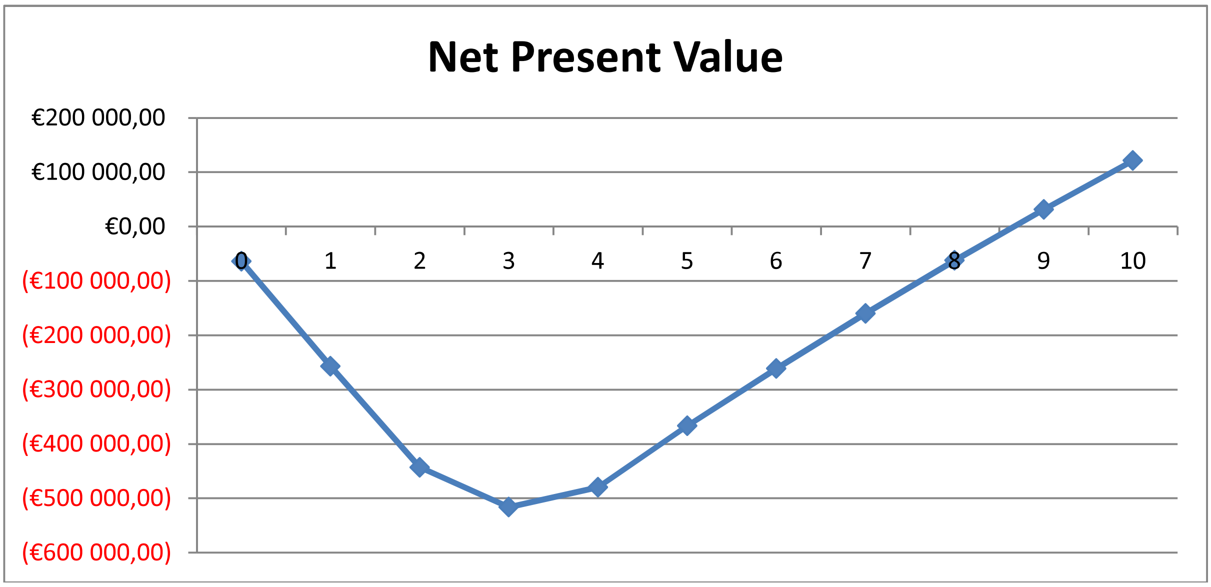

Figure 3. Cost-Benefit difference in a 10-years horizon with a fee of 680€ (without VAT) per vehicle and year

S2 analysis

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:

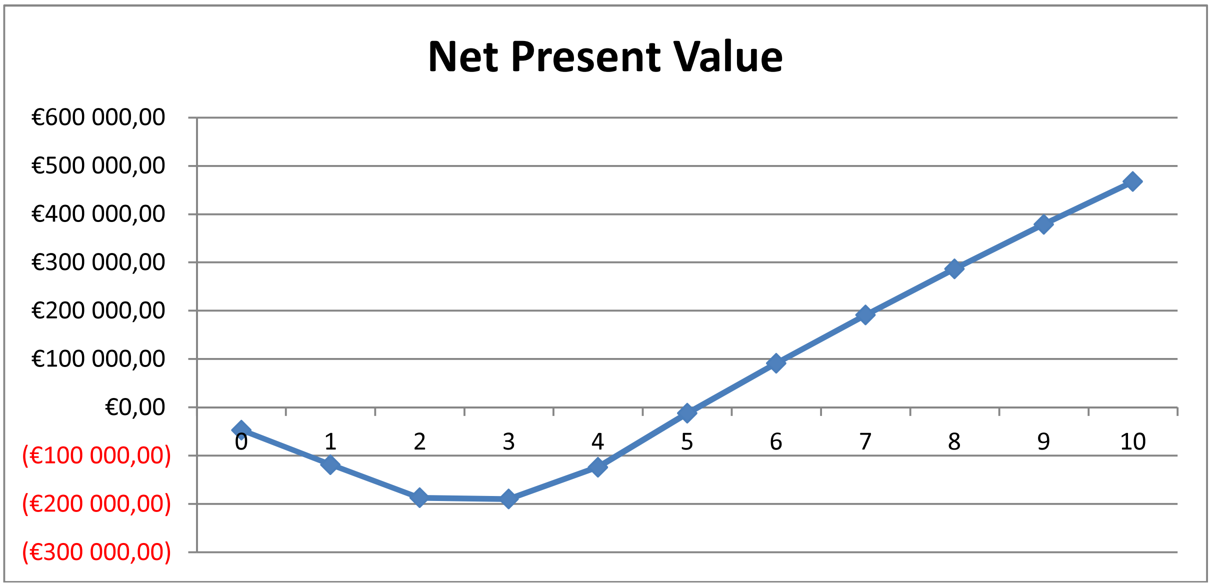

Figure 4. NPV trends in a 10-years horizon

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.

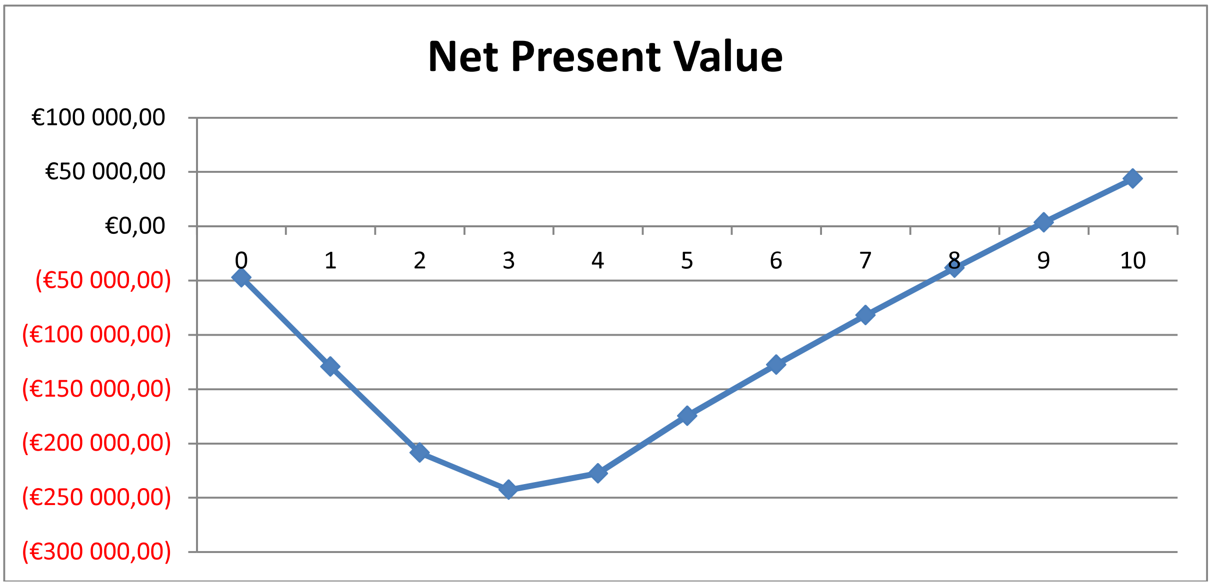

Figure 5. Cost-Benefit difference in a 10-years horizon with a fee of 360 € per vehicle and year

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.

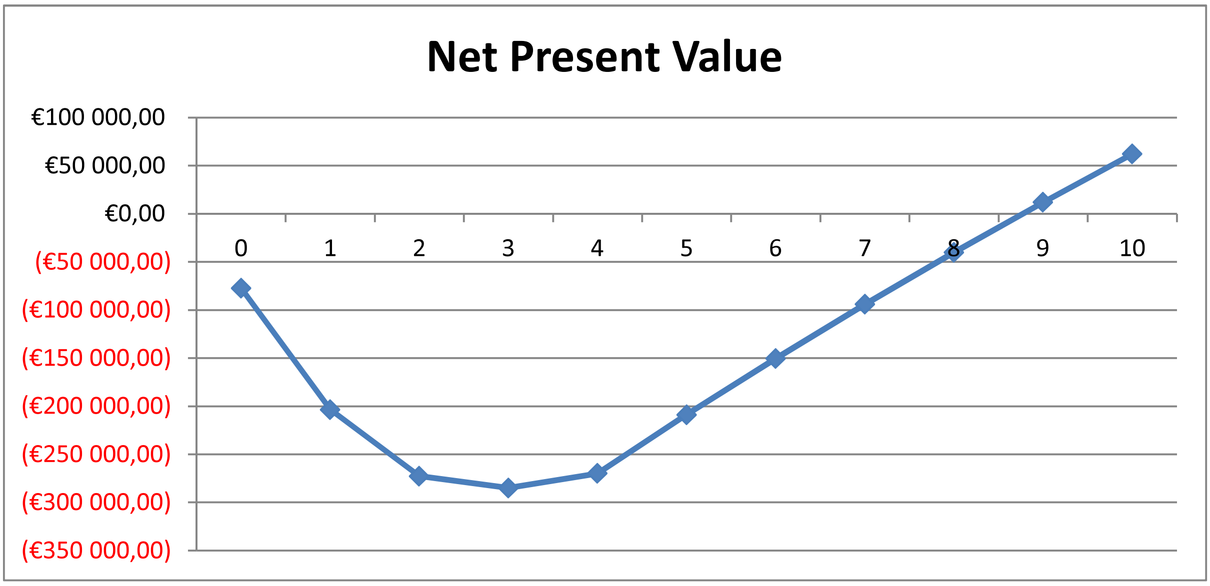

Figure 6. Cost-Benefit difference in a 10-years horizon with 100 scheduled DSB systems and a fee of 300 € per vehicle and year (including VAT)

<u>S3 analysis</u>

- *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[3].
- 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):

	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						

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

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 €**

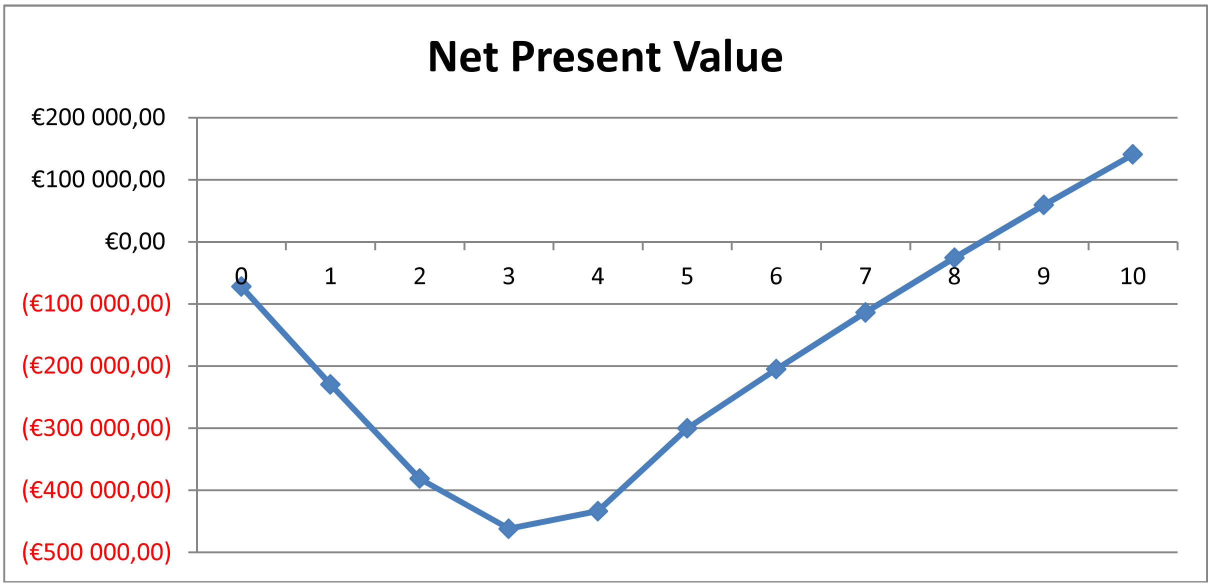

Figure 7. Cost-Benefit difference in a 10-years horizon with the panel solution

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.

3.1.4.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.

3.1.5. 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 6) 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 2. 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 3. 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 €
CO_2 gains-Traffic	0,00 €	2.416,07 €	5.315,35 €	7.248,21 €	8.697,85 €	9.664,28 €	9.664,28 €
CO_2 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 CO_2 emission gains that public authorities will earn in a hypothesis of a carbon tax that public authorities had to pay.

3.1.6. 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 4. 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.

3.2. Energy Efficient Intersection Control

3.2.1. 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 5. 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

3.2.2. Scenario characteristics and hypotheses

In the Cost Benefit Analysis, three possibilities are tested:

- S1: Cooperative system in the BUA[4] 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.
- 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

[4] Business as usual

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.

3.2.3.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:

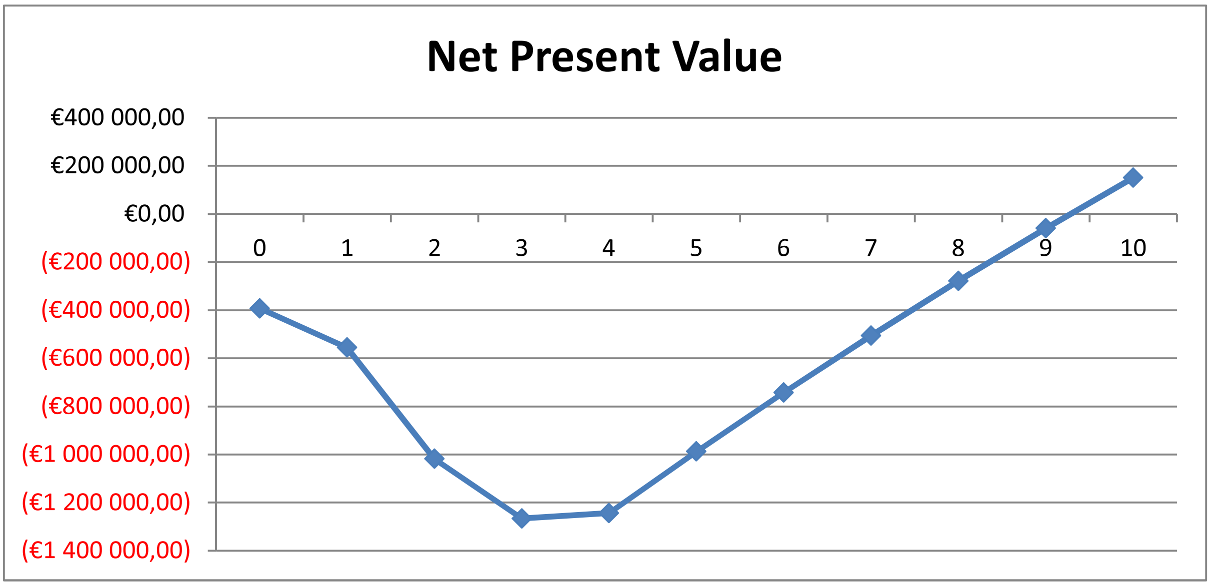

Figure 8. NPV evolution in a 10-years horizon with current settings and a yearly fee of 400 €/vehicle with VAT

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:

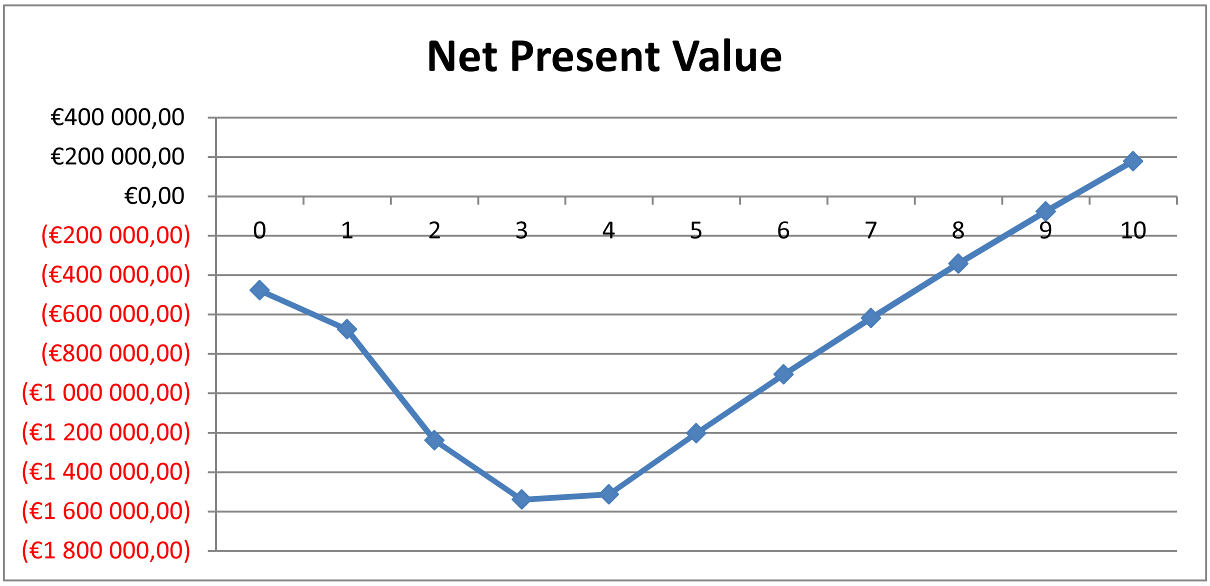

Figure 9. NPV evolution in a 10-years horizon with current settings and a yearly fee of 460 €/vehicle with VAT

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).

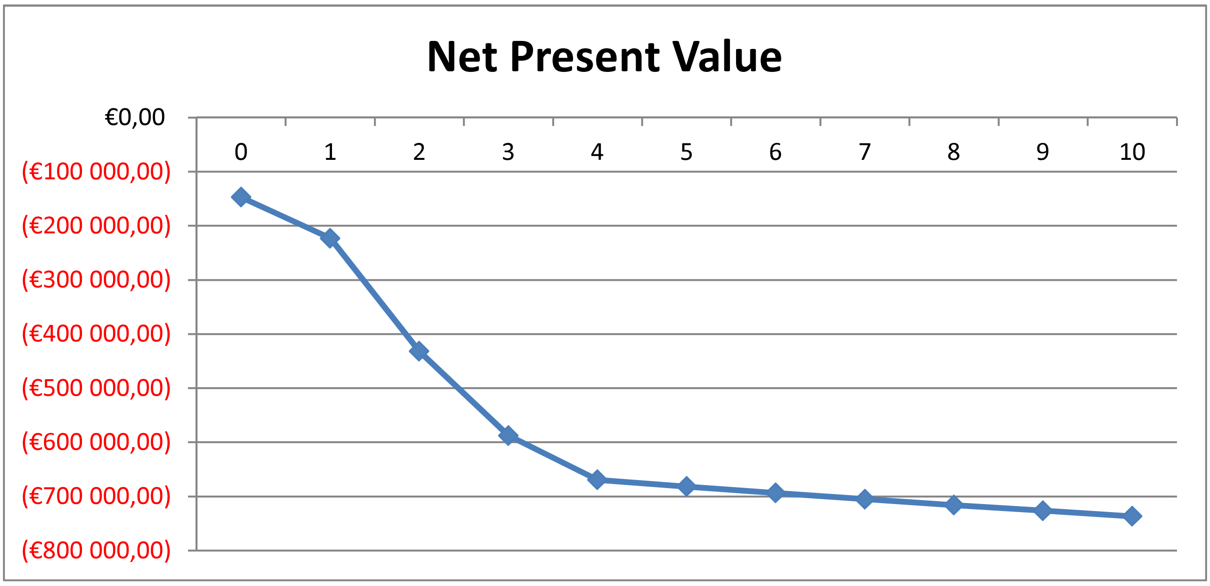

Figure 10. NPV evolution in a 10-years horizon with a green wave and no fee

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

3.2.4.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.

3.2.5. 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 6. 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).

<u>S1 analysis</u>

- *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:

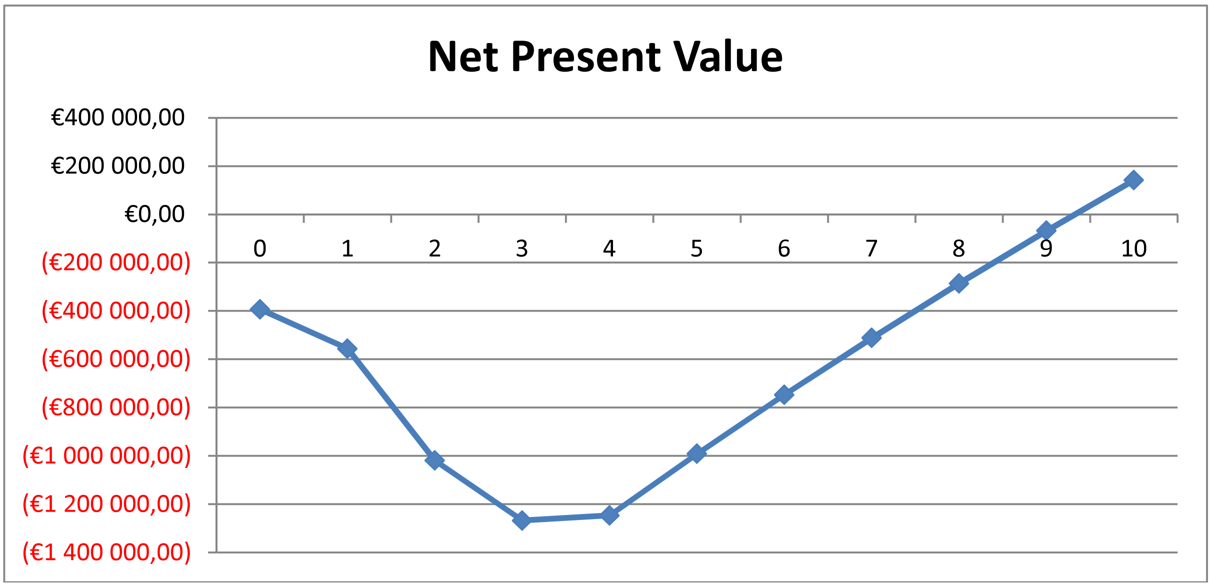

Figure 11. NPV evolution in a 10-years horizon with current settings and a yearly fee of 400 €/vehicle with VAT

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:

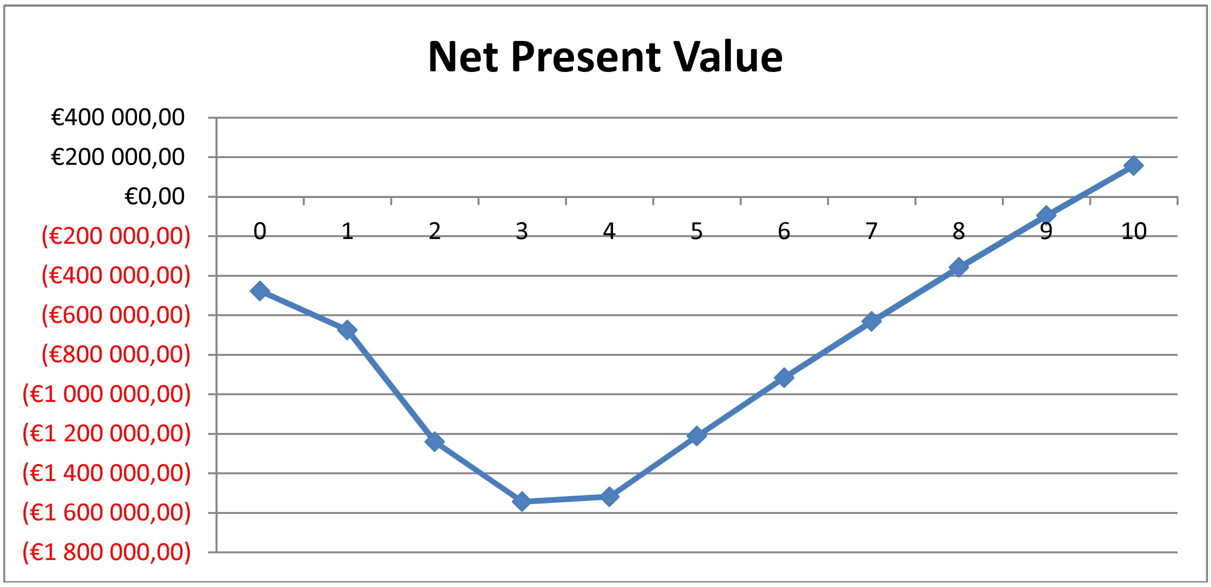

Figure 12. NPV evolution in a 10-years horizon with current settings and a yearly fee of 390 €/vehicle with VAT

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:

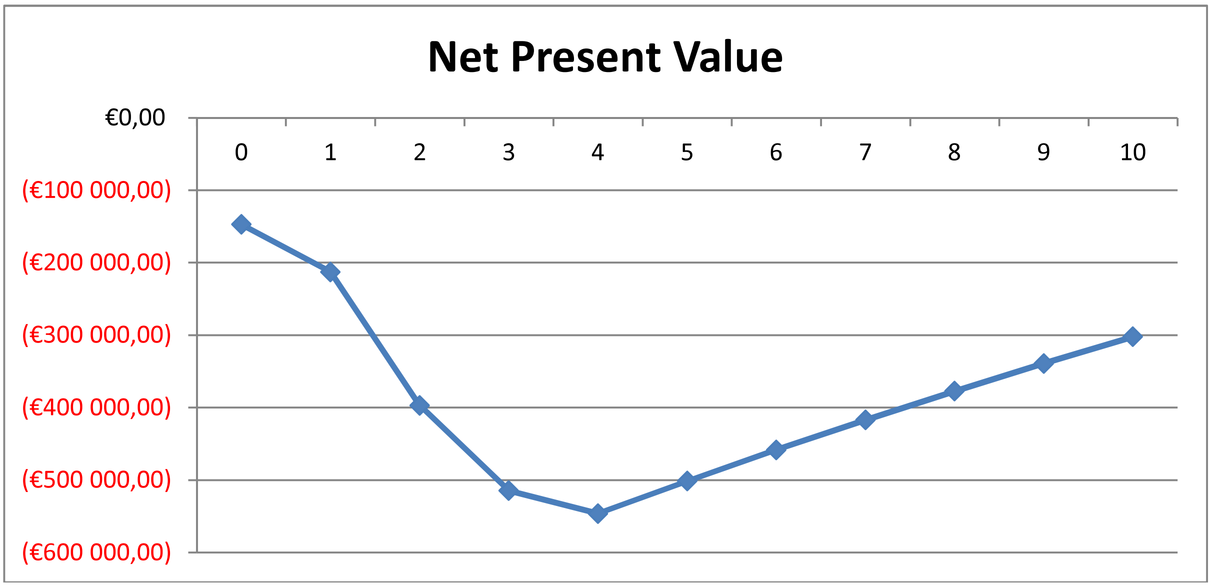

Figure 13. NPV evolution in a 10-years horizon with current settings but no fee (green wave)

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 (Routhier, 2002), 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:

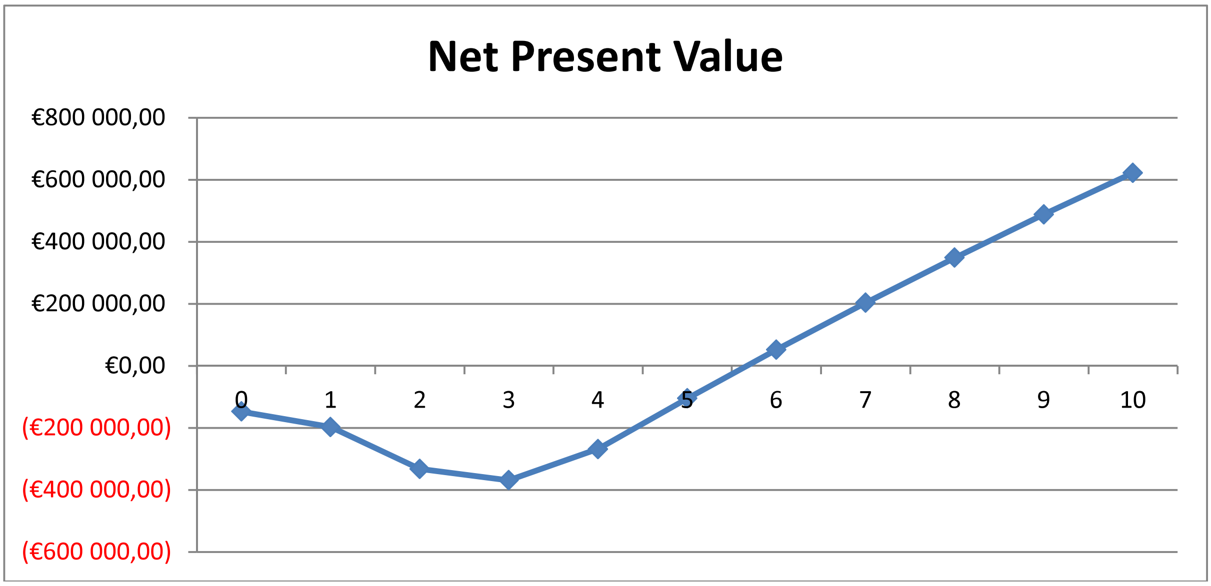

Figure 14. NPV evolution in a 10-years horizon with 4000 vehicles using the green wave after year 4.

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

3.2.6. 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 7. 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.

3.3. *In-vehicle systems*

3.3.1.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 8. Gains of using in-vehicle systems. Results extrapolated from evaluation conclusions

3.3.2.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.

3.3.3.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:

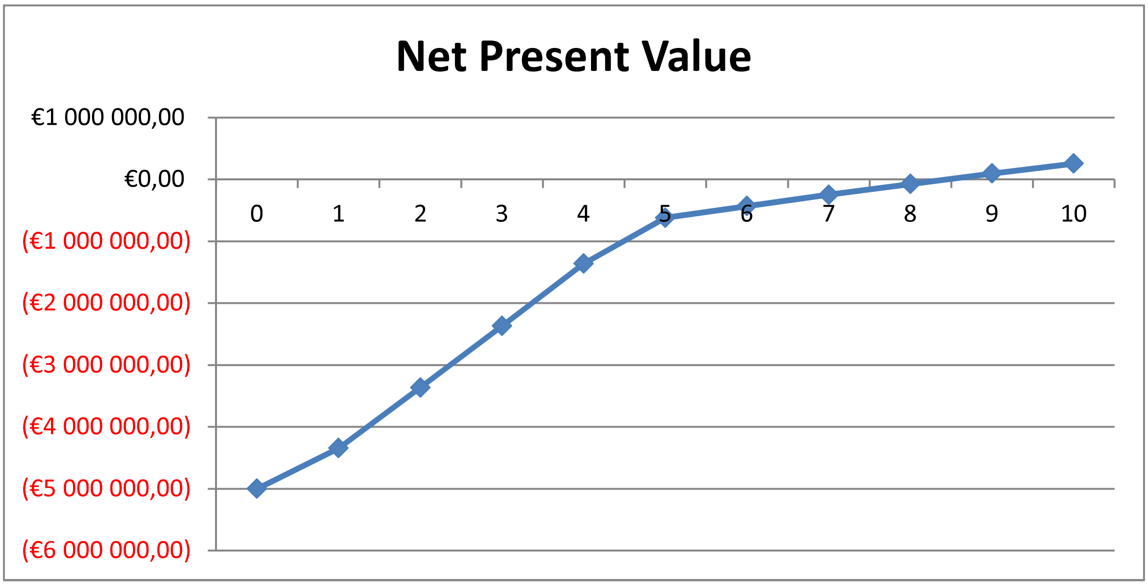

Figure 15. NPV evolution in a 10-years horizon with current settings

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.

S2 analysis

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:

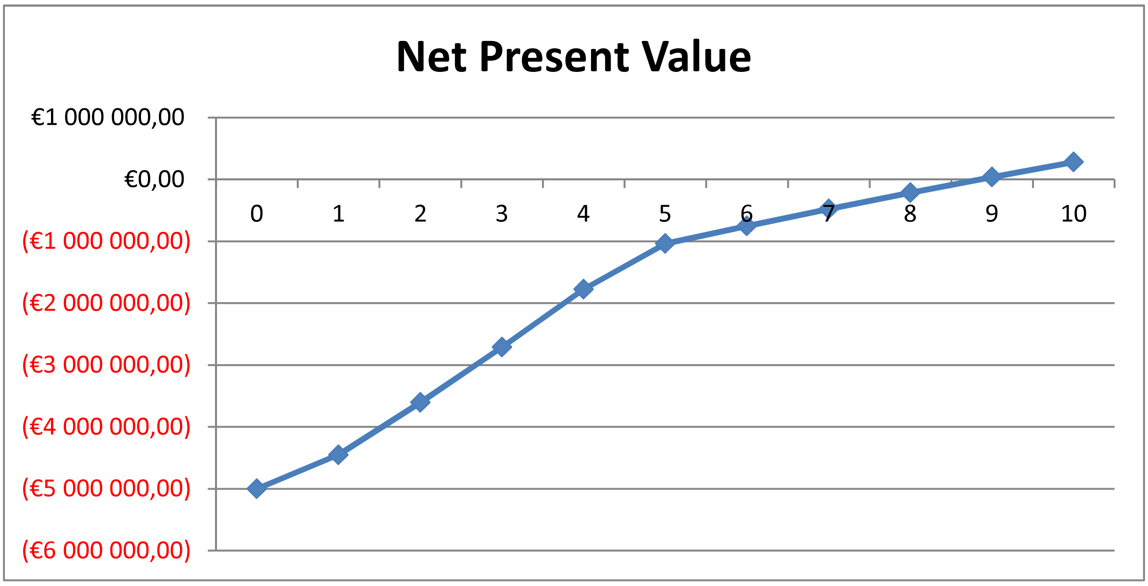

Figure 16. NPV evolution in a 10-years horizon with current settings

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

3.3.4.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.

3.3.5. 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 9. 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 10. 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.

4. General Conclusions

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.

4.1. 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.

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6. Table of figures

Figure 1: 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) 10

Figure 2. 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) 16

Figure 3. Cost-Benefit difference in a 10-years horizon with a fee of 680€ (without VAT) per vehicle and year 17

Figure 4. NPV trends in a 10-years horizon 18

Figure 5. Cost-Benefit difference in a 10-years horizon with a fee of 360 € per vehicle and year 19

Figure 6. Cost-Benefit difference in a 10-years horizon with 100 scheduled DSB systems and a fee of 300 € per vehicle and year (including VAT) 21

Figure 7. Cost-Benefit difference in a 10-years horizon with the panel solution 23

Figure 8. NPV evolution in a 10-years horizon with current settings and a yearly fee of 400 €/vehicle with VAT 31

Figure 9. NPV evolution in a 10-years horizon with current settings and a yearly fee of 460 €/vehicle with VAT 32

Figure 10. NPV evolution in a 10-years horizon with a green wave and no fee 34

Figure 11. NPV evolution in a 10-years horizon with current settings and a yearly fee of 400 €/vehicle with VAT 37

Figure 12. NPV evolution in a 10-years horizon with current settings and a yearly fee of 390 €/vehicle with VAT 39

Figure 13. NPV evolution in a 10-years horizon with current settings but no fee (green wave) 40

Figure 14. NPV evolution in a 10-years horizon with 4000 vehicles using the green wave after year 4. 41

Figure 15. NPV evolution in a 10-years horizon with current settings 44

Figure 16. NPV evolution in a 10-years horizon with current settings 46

7. Tables

Table 1. 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. 13

Table 2. Fuel and CO_2 savings for DSB in a deployment situation.. 24

Table 3. Benefits for transport carriers (DSB) 25

Table 4. Costs of implementing the DSB systems on cities of different size 26

Table 5. 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 28

Table 6. Fuel and CO2 gaps for EEIC in a deployment situation (a negative value indicates a reduction, a positive value an increase) 35

Table 7. IRR for different categories of cities 41

Table 8. Gains of using in-vehicle systems. Results extrapolated from evaluation conclusions 42

Table 9. Application of AL to different cities 47

Table 10. Application of EDS to different cities 47