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Abstract:_____________This report includes a detailed cost benefit analysis of the integrated traffic & mobility management and traveller information systems that were developed in the framework of SEE-ITS. The overall benefits and costs from a future implementation of the aforementioned systems are being computed for Greece.

EXECUTIVE SUMMARY

This report includes a detailed cost benefit analysis of the integrated traffic & mobility management and traveller information systems that were developed in the framework of SEE-ITS. The overall benefits and costs from a future implementation of the aforementioned systems are being computed for Greece.

The adequate techniques for the transformation of qualitative criteria (environmental, social) are also being identified and applied for the computation of the external effects. The computation of costs and benefits follows the analytical CBA procedure, namely the analysis is composed by three different perspectives: the user perspective, the operator's perspective and the government's perspective. The overall welfare of the society for Greece is the sum of the three separate perspectives. The output of this activity is the analytical recording of all costs and benefits, along with the overall impact to social welfare for each demo case.

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1. COST-BENEFIT ANALYSIS OF ITS

The appraisal of a transportation project seeks to evaluate the value for money of this project. Investments on the transportation sector usually affect many different parties (i.e. public transport agencies, transport users, businesses, land owners etc.). Each of these parties is interested in quantifying the impacts of a transportation project from his/her viewpoint. However, an economic analysis that is conducted within the context of a transport project appraisal aims to identify the social benefit of the transport project.

In this present document a framework is proposed for the conduct of such an economic analysis. The proposed framework approach is a cost-benefit analysis (CBA). A CBA compares costs and benefits (in monetary units) of an application incurred in a specific time period and spatial dimension (e.g. highway corridor). As a comparative tool CBA assesses the difference between project alternatives (i.e. capital investment alternatives) and a Base Case Alternative (i.e. “Do minimum” alternative). A “Do minimum” alternative should be the most plausible yet efficient utilization of the stock of capital resources that is likely to be available over the life of the proposed project, without additional investment.

Transportation projects normally require large initial investments and are expected to generate benefits extending far into the future. Thus, a need is created to compare benefits and costs that occur at different points in time. Since money has a time value, the same amount of money at different times does not have the same value. Therefore, it is important to convert costs and benefits (i.e. “cash flows”) into equivalent values when conducting a CBA.

1.1. Overview of CBA in Transport

The primary goal of an economic assessment of a transport project is to quantify the magnitude of the economic impact resulting from an investment in the transportation sector. The cumulative economic impact is a function of the change in transport user benefits (i.e. consumer’s surplus), the change in system operating costs and revenues (i.e. producer surplus), the change in cost of externalities (i.e. environmental costs, accidents, etc.), and finally the investments costs.

Monetizing the abovementioned changes is a rather demanding task, since it is necessary to consider:

- The scope of the analysis in terms of mode, study area and range of impacts;
- The definition of the alternatives – particularly the “Do minimum” alternative;
- The estimation of transport user benefits (consumer surplus);
- The estimation of impacts on transport providers and the government (includes producer surplus and investment costs);
- Monetization of time and safety;

- Consideration of environmental impacts and other externalities;
- The mechanics of the process including inputs, project life, discounting, aggregation of benefits and costs, unit of account.

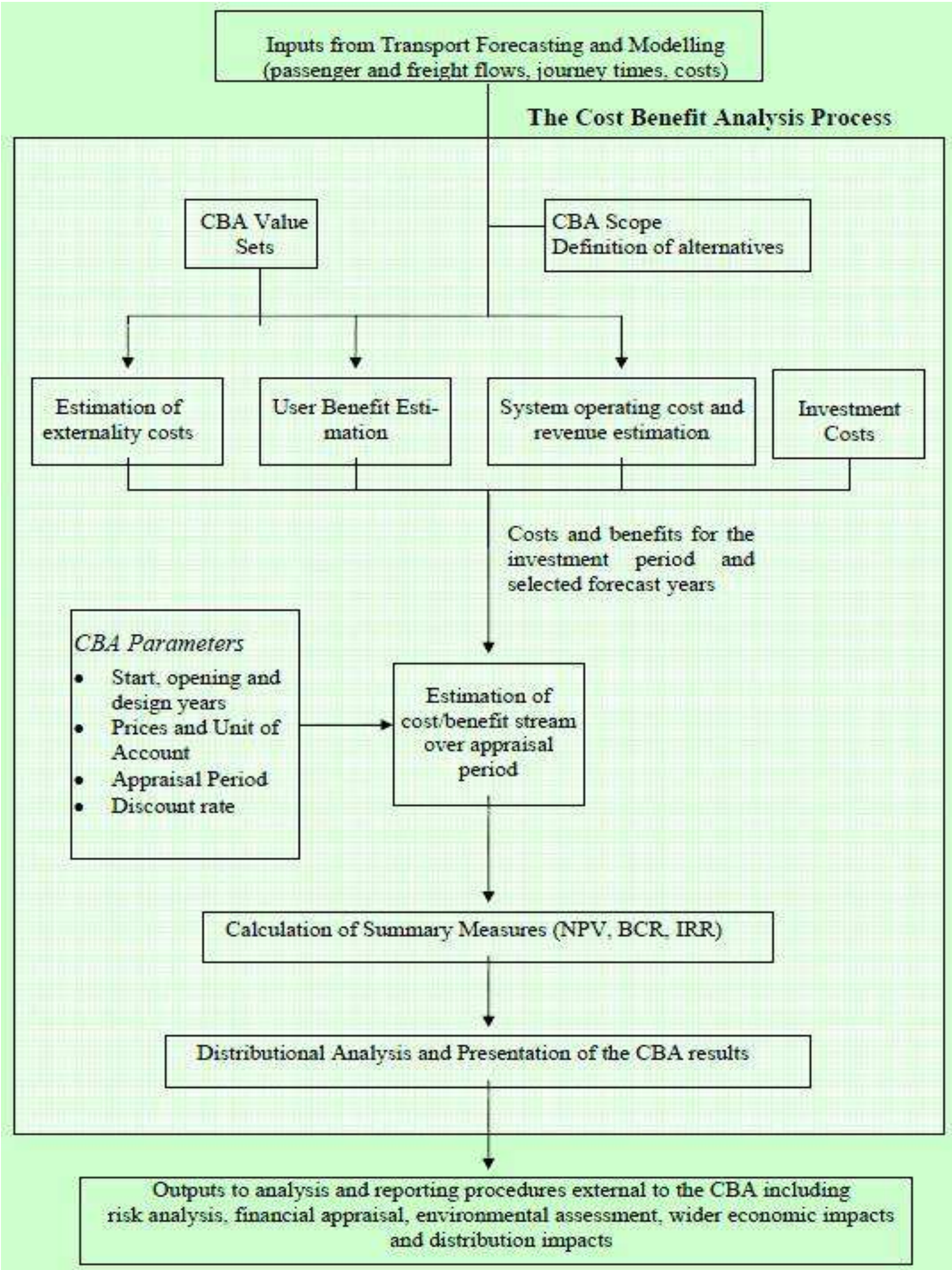

Figure 1: Flowchart of Transport Economic Appraisal (*Source: HEATCO D5 [1]*)

1.2. Scope of the CBA

In order to define the scope of a CBA it is critical to delineate the study area, determine the modes of transports that should be considered in the analysis, and identify the impacts of the transport project. Regarding impacts, the estimation of changes in producer and consumer surplus demands the measurement of benefits, revenues and costs to transport operators and users. These should at least include the investment cost and changes in infrastructure and system maintenance and operating costs, travel times, safety, user charges and operator revenues. As far as the modes of transport are concerned, those should be considered that will use the new infrastructure, along with those from which demand may be abstracted. Finally, the study area should be small enough to facilitate the estimation of accurate results.

1.3. Estimation of consumer's surplus and travel time savings

Monetization of transport user benefits requires the quantification of consumer's surplus. Consumer's surplus has been defined as the excess of consumer willingness to pay over the cost of a trip. Normally, what is of interest is the change in consumer surplus occurring from some change in the cost of travel incurred by an improvement in transport conditions. However, in the transportation field, money costs are only a part of the composite travel cost. In reality the cost of travel also encompasses the time spent by the users, access time to public transport, discomfort, perceived safety risk and other elements. Thus, price alone is not an accurate estimate of the cost of travel of the consumer's willingness to pay, instead generalized cost is used.

Generalized cost is an amount of money representing the overall cost and inconvenience to the transport user of travelling between a particular origin and destination by a particular mode. In practice, generalized cost is usually limited to a number of impacts which when added constitute the components of user benefit:

1. Time costs (Time in minutes * Value of Time in €/minute);
2. User charges (e.g. fares/tolls); and
3. Operating costs for private vehicles.

It is critical though to mention that the components of generalized cost differ among the different transportation modes. Thus, there is a substantial difference in the reported user's benefits for users of different modes. Moreover, it should be noted that Value of Time varies between individuals and even for the same individual, depending for example on the trip purpose. Thus, there is no unique willingness-to-pay for travel time savings.

Given the significance of the Value of Time in the estimation of the generalized cost of travel and in consequence the consumer's surplus, it is recommended that local values should be used whenever possible, provided that they have been produced according to a coherent and well justified methodology. In the case that no such values exist, then default values obtained from international analyses of value of time studies should be used (e.g. Developing Harmonized European Approaches for Transport Costing and Project Assessment [1]). In the abovementioned study different valuation methods of Value of Time have been used for different trip purposes.

1.4. Estimation of Producer's Surplus

Since CBA is concerned about the social welfare and not only the consumer's surplus, the producer's surplus should be estimated as well. Producer's surplus is defined simply as the total revenue minus total costs. However, regarding producer's surplus, it should be emphasized at this point that if the additional demand for this service is associated with reduced consumption of some other goods or services elsewhere in the economy, those goods and services are being priced at marginal cost, so that there is no offsetting or additional change in producer surplus elsewhere.

1.5. Investment Costs

The investment costs for transport infrastructure projects are normally dictated from engineering design studies and estimates. However, necessary adjustments have to be applied to these engineering cost estimates before they can be considered for the economic analysis. Adjustments should account for **Inflation** (between year of the engineering cost estimate and price base of the appraisal).

No adjustments are required for the method of the project financing. The investment costs are the same whether or not the project is financed directly by the government or through some form of private sector involvement (i.e. public private partnerships). Moreover, it is important that user benefits reflect any travel time and cost delays during construction, although they cannot be directly accounted as investment costs.

1.6. Maintenance and Operating Costs

Appropriate estimates are also necessary for the costs of infrastructure and services operation, which are mode and country-specific. The main costs are commonly:

- The costs of infrastructure operation;
- Maintenance costs;
- Changes in the vehicle operating costs of public transport services.

Additionally, any disruption to transport users that occurs during periods of routine maintenance should be reflected in the appraisal as a user benefit impact.

1.7. Safety related Benefits

Safety is not treated like the other components of user benefit. Instead of being considered as a component of generalized cost per trip, accidents and casualties are typically treated as random, occasional costs arising from the transport system. These costs are estimated by applying unit values per accident and per casualty. The calculation is a simple multiplication of forecasted accident numbers (by severity) with the costs of accidents (by severity). This approach is similar to that of externalities (e.g. the environment).

Accidents costs are comprised by direct economic costs, indirect economic costs, costs of material damage, and a value of safety per se:

- Value of safety per se: willingness to pay for protecting human life based on stated preference studies carried out in the country concerned.
- Direct and indirect economic costs (mainly medical and rehabilitation cost, administrative cost of legal system, and production losses).
- Material damage from accidents: cost values for the average damage caused by accidents in the country under assessment.

Estimates for the value of safety per se, direct and indirect economic costs, and material damage can be found in the following project report "Developing Harmonized European Approaches for Transport Costing and Project Assessment [1]" regarding EU member countries.

1.8. Environmental Impacts of a Transport Project

Investments on ITS technologies and infrastructure can possibly generate significant benefits regarding the surrounding environment (i.e. natural and man-made). Within the context of a CBA analysis attention is being placed on the assessment of environmental effects such as air pollution, noise and global warming. Monetary measures are proposed below for the valuation of these environmental impacts. In order to quantify the positive effects of the transport project on air pollution the following calculation procedure is recommended:

Step 1: quantification of change in pollutant emissions (NOx, SO2, NMVOC, PM2.5/PM10) due to a project, measured in tonnes, using state-of-the-art national or European emission factors.

Step 2: classification of emissions according to local environment (urban – outside built-up areas).

Step 3: preparation of the cost factor table by increasing the cost factor according to the assumed country-specific GDP per capita growth for each year of the analysis.

Step 4: calculation of impacts (multiplication of pollutant emissions by impact factor) and costs (multiplication of pollutant emissions by cost factor).

Step 5: reporting of impacts and costs.

The monetization of noise costs should be obtained according to the subsequent estimation procedure:

Step 1: quantification of the number of persons exposed to certain noise levels (should be available from noise calculations) for the Do-Minimum case and the Do-Something case.

Step 2: preparation of the cost factor table by increasing the cost factor according to the assumed country-specific GDP per capita growth for each year of the analysis.

Step 3: calculation of impacts (multiply percentage of highly annoyed persons by number of persons exposed) and costs (multiply cost per person by number of persons exposed) for both cases.

Step 4: subtraction of total costs for the Do-Something case from Do-Minimum case

Step 5: reporting of costs and impacts (change in number of people highly annoyed).

Accordingly, the estimation of costs due to the emission of greenhouse gases (usually expressed as CO2 equivalents) is conducted by multiplying the amount of CO2 equivalents emitted with a cost factor. The calculation steps are the following:

Step 1: quantification of change in greenhouse gas emissions (i.e. CO2) due to a project measured in tonnes.

Step 2: multiplication of CO2 equivalents with cost factor for year of emission.

Step 3: reporting of emissions and costs.

Values for the corresponding emission and noise cost factors can be obtained from the following project report "Developing Harmonized European Approaches for Transport Costing and Project Assessment [1]" regarding EU member countries.

1.9. Evaluation Criteria

Costs and benefits have to be converted into equivalent present values prior to the estimation of the evaluation criteria on which the project assessment will be based. Thus, the base year of the evaluation has to be initially determined. All past investment costs have to be converted into present values (with respect to the base year of the valuation) according to the inflation rate of the corresponding country where the investment is taking place. All future costs (i.e. operation and maintenance) and benefits have to be converted into equivalent present values according to the present value formula:

$$P = F^*(1+r)^N \quad \text{(Eq. 1)}$$

, where P is the present value, F is the future amount, r is the social discount rate, and N is the project lifetime.

The abovementioned conversions require the knowledge of the project lifetime (i.e. typically ranges between 5 – 10 years for ITS projects), the inflation rate as well as the social discount rate. The social discount rate represents the way money now is worth more than money later. It determines by how much any future amount is discounted or reduced, to make it correspond to an equivalent amount today. It is generally specified as a constant rate over time (i.e. reference social discount rate is 5.5% for EU transport projects [2]).

There are three evaluation criteria that can be used for the economic assessment of a transport project:

- Net Present Value (NPV);
- Benefit-Cost Ratio; and
- Internal Rate of Return (IRR)

The net present value is defined as the difference between benefits and costs. NPV focuses attention on quantity of money, which is what the evaluation is ultimately concerned with. However, it only provides a good comparison between projects when they are strictly comparable in terms of level of investment or total budgets. Benefit-cost ratio is a non-dimensional index of economic evaluation. It allows the comparison of projects on a common scale and provides an easy mean to rank objects in order of relative merit. However, since values change depending on how costs and benefits are counted, there has been frequently observed a tendency to manipulate the data. Finally, the internal rate of return is the discount rate for which the net present value of a project is zero. The internal rate of return introduces the notion of “return on investment” and the project with the highest IRR is ranked as top. The advantages of the IRR is that it eliminates the need to argue about the appropriate discount rate and that rankings cannot be manipulated by the choice of the discount rate. On the other side, such an evaluation could possibly lead to two or more solutions; one cannot really tell what the IRR is.

2. Cost-Benefit Analysis of ATIS in Greece

2.1. Introduction

The framework of the demonstration activities in Greece relates to the provision of Advanced Traveller Information Services (ATIS). The systems developed in Thessaloniki and in Patras have been evaluated at the previous project activities 5.3 and 6.1. The impact assessment has been conducted at regional and national level respectively. In the context of the present activity the evaluation is finalized with the examination and the determination of the economic feasibility of the systems, with the conduct of a cost-benefit analysis.

2.1.1. Analysis of Costs

The first element of the cost benefit analysis is the cost determination of the systems. Regarding the Greek system, the investment cost is related to the purchase of the equipment and its installation. In Thessaloniki 25 Bluetooth (BT) devices have been installed. The total installation costs regarding the roadside equipment is 57.500 €. Moreover the system has been integrated into the local mobility centre of Thessaloniki and therefore the information provision also takes place through the roadside Variable Message Signs (VMS). It has to be mentioned that VMS have not been installed within the framework of SEE-ITS project, but in this cost-benefit analysis their cost will be considered for the system's evaluation. Each VMS has a value of 48.000 € and the installation of 4 VMS devices has a total cost of 192.000 €. Moreover the development of the software, which is necessary for the data fusion and the data provision, costs 60.000 €. The total development cost is estimated to be 309.500 €. Detailed description of the initial investment cost is provided in Table 1.

Table 1: Initial investment cost of ATIS in Greece.

Cost	Description	Cost / Unit	Units	Total cost
BT sensors	Purchase of equipment, cost of installation, other costs, guarantee for 3 years	2.300 €	25	57.500 €
VMS devices	Purchase of equipment, cost of installation, other development costs	48.000 €	4	192.000 €
Software	Development of data fusion software and information provision platform.	-		60.000 €
Total cost				309.500 €

Apart from the development cost which is all paid before the final demonstration of the system, for every year of operation an extra amount is accounted for the system's operation and maintenance. These costs are mainly comprised of the telecommunication and the power supply costs, while no personnel costs are included since the system is integrated into the mobility centre of the area. Considering a monthly operational cost of 95.00 € per unit, its annual value is estimated to be approximately 2.755 €. An extra maintenance cost is also added to this cost which is expected to occur after the first three years of implementation and it includes the possible replacement of various parts or unforeseen events. The total amount of this cost is also expected to be 2.755 € per year. The description of the operation and maintenance costs per installed unit is presented in Table 2.

Table 2: Annual operation and maintenance cost of the Greek system.

Cost	Description	Cost per unit	Total cost
Operational Cost	Telecommunications costs & power supply	95 €	2.755 €
	Personnel Costs	0,00 €	-
Maintenance Cost	Possible replacements of various parts (batteries, wires etc.)	95 €	2.755 €
	Personnel Costs	0,00 €	-

The investment cost has been paid out entirety in 2013, while the operational costs start in 2014 (the first year of operation) and remain constant for the following years. On the other hand the maintenance costs start after the first three years of the implementation and remain constant for the following years. The system's costs are extended for the following 7 years into the future. In these values the opportunity cost and the risk of the investment should be taken into account. This is achieved by discounting the future cash flows to present values. Therefore, using a social discount rate of 7%, the present value for each year having as a reference the year of 2013, is calculated using Equation 1. The total net present value of the infrastructure, operation and maintenance costs is estimated to be 334.357 €. The calculated values for the system's costs are presented in Table 3.

Table 3: Detailed cost description of the implementation of an ATIS system in Thessaloniki

Costs	2013	2014	2015	2016	2017	2018	2019	2020
Development (€)	309.500	0	0	0	0	0	0	0
Operation & Maintenance (€)	0	2.755	2.755	5.550	5.550	5.550	5.550	5.550
Total (€)	309.500	2.755	2.755	5.550	5.550	5.550	5.550	5.550
Discounted Total (€)	309.500	2.575	2.406	4.530	4.234	3.957	3.698	3.456
Total Cost (€)								334.357

(Present Value)

2.1.2. Analysis of Benefits

Transport projects can provide wider benefits for users and society. Therefore the need for the monetization of benefits and the internalization of externalities is essential when performing cost benefit analyses. Except for the direct benefit of fuel consumption savings, there are also indirect benefits, that are not immediately beneficial to the individual users (in monetary terms), but increase the total social welfare. In a cost-benefit analysis framework all the benefits should be quantified and converted to monetized values. For example, although it is easy to comprehend the economic benefits arising from travel-time savings, it is difficult to quantify this benefit. The task of estimating the incorporated costs in accidents, travel time, fuel consumption and CO_2 emissions, is facilitated by using the relevant cost factors provided in the HEATCO report. The cost factors found in HEATCO have to be updated since the project was finalized in 2006 and the estimated values of the cost factors represent 2002 socio-economic conditions. It is thus necessary to convert these values to present values (i.e. 2014 values), in order to monetize the projected benefits. The adjustment of the cost factors is done based on the annual growth rate of GDP per capita of the corresponding country that the ITS project has been implemented. Detailed information of the annual growth rate of the GDP per capita for each country is provided in the website of The World Bank. The annual growth rate of GDP per capita in Greece since 2002 is presented in Table 4.

Table 4: Annual Growth Rate of GDP/capita in Greece since 2002

Year	Annual Growth Rate of GDP/capita
2002	0,031
2003	0,056
2004	0,04
2005	0,019
2006	0,052
2007	0,032
2008	-0,004
2009	-0,031
2010	-0,047
2011	-0,069
2012	-0,067
2013	-0,033

For the Greek system the benefits that have been identified are travel-time, fuel consumption and CO_2 emissions savings. The values of travel time provided by HEATCO represent 2002 values. Therefore these are converted to 2014 present values using the annual growth rate of the GDP, as shown in Table 5.

Table 5: Value of travel time per year in Greece since 2002.

Year	VTT
2002	19.42
2003	20.51
2004	21.33
2005	21.73
2006	22.86
2007	23.59
2008	23.50
2009	22.77
2010	21.70
2011	20.20
2012	18.85
2013	18.23

For CO_2 emissions costs factors, relevant values are provided for the year 2014 in HEATCO, and therefore no adjustment is needed. Regarding fuel consumption, current market values are used. At this point it has to be mentioned that 2014 cost factors will be used for the estimation of future year benefits, to avoid overestimation of benefits. Therefore the cost factors of the parameters defined for the Greek system and for the year 2014 are presented on the table below.

Table 6: Cost factors for the Greek system

Value of Travel Time (€/hour)	Value of Fuel (€/litre)	Value of CO_2 Emissions (€/tonne)
18,23	1,55 for Petrol 1,23 for Diesel 1,486 (80% Petrol and 20% Diesel	26

After determining the costs factors, the next step is the identification of the impacts of the system on the pilot site area that is implemented. This analysis evaluates the implementation of the system in the city of Thessaloniki. Vehicle-hours travelled, fuel consumption and CO_2 emissions per annum for the city of Thessaloniki, as reported in activity 6.1, are provided in Table 7.

Table 7: Transport related statistical data of Thessaloniki.

Total VHT	Total fuel consumption	Total CO_2 emissions
96.574.255	303 kilo-tons	907,5 kilo-tons

The benefits of the system are realized a year after the installation and deployment of the system. These benefits are provided in Table 8:

Table 8: Benefits of the ATIS demo system implementation in Thessaloniki.

VHT reduction	Fuel consumption reduction	CO_2 emissions reduction
Up to 2%	Up to 4%	Up to 4%

These benefits correspond to the first year of the system implementation, and are considered to be reducing gradually until 2020, which is the end of the project's lifespan. Since some traffic performance measures and statistics have been derived from Thessaloniki's VISUM model (i.e. total vehicle-hours and total vehicle-km travelled in the area) and others (i.e. fuel consumption, and emissions) have been extracted based on these data, adjustments should be made on the identified impacts because the system is applied on a smaller area than the geographical extent of the model. Thus, vehicle-hours travelled, fuel consumption and emissions presented in Table 7 could be reduced by up to 90%. The benefits that arise from the implementation of the project are provided in Table 9. Taking into account the costs and benefits of the project in net present values terms, then the cost benefit ratio is 14,19.

Table 9: Benefits from the implementation of an ATIS in Thessaloniki.

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of Vehicle-hours	115889	38630	12877	4292	1431	477	159
Value of Travel Time (€/hour)	18,23	18,23	18,23	18,23	18,23	18,23	18,23
Travel time savings (€)	2112480	704160	234720	78240	26080	8693	2898
Discounted Values (€)	1974280	615041	191601	59689	18595	5793	1805
Reduction of CO2 emissions (tons)	2424	808	269	90	30	10	3
Cost factor (€/ton)	26	26	26	26	26	26	26
Savings (€)	63024	21008	7003	2334	778	259	86
Discounted Values (€)	58901	18349	5716	1781	555	173	54
Total Benefit (€) (Present Value)	2424	808	269	90	30	10	3
Reduction of consumed Petrol (litters)	635600	211866,67	70622,222	23540,74	7846,914	2615,64	871,879
Price of petrol (€/litter)	1,55	1,55	1,55	1,55	1,55	1,55	1,55
Savings (€)	985180	328393	109464	36488	12163	4054	1351
Reduction of consumed Diesel (litters)	272400	90800	30267	10089	3363	1121	374
Price of diesel (€/litter)	1,23	1,23	1,23	1,23	1,23	1,23	1,23
Savings (€)	335052	111684	37228	12409,33	4136,444	1378,81	459,605
Total Savings from Reduction of Fuel Consumption (€)	1320232	440077	146692	48897	16299	5433	1811
Discounted Values (€)	1233862	384381	119745	37304	11621	3620	1128
Total Benefit (€) (Present Value)							4.743.991

3. COST-BENEFIT ANALYSIS OF COOPERATIVE TRAFFIC MANAGEMENT IN GREECE

3.1. Introduction

The feasibility of the implementation of a cooperative intelligent transportation system in the city of Thessaloniki is assessed in economic terms. This system has been already installed and piloted in the City of Vienna within the context of the SEE-ITS project. The evaluation of the system's operation and performance has been presented in project activity 5.3. The potential transferrable impacts of Vienna's pilot system to Thessaloniki's road transport network operations have been determined and quantified in project activities 5.3 and 6.1. The CBA presented subsequently is based on the information provided in the aforementioned activities.

3.1.1. Analysis of Costs

Initially, the total cost of the system, throughout the project's evaluation lifespan (i.e. 7 years), has to be estimated. This cost is comprised of the development, operations and maintenance costs.

The development cost corresponds to the building of the software and the end-user application, the server, as well as for the planning and set up of the system. This cost was 100.000€ for Vienna's pilot site. For the implementation of the same system in Thessaloniki the development cost has to be adjusted in order to be representative of the current Greek economic conditions. This adjustment is based on the GDP per capita (PPP) of Austria and Greece during the base year of the project's evaluation lifecycle. The ratio of the Greek GDP per capita (PPP) to Austria's GDP per capita (PPP) is estimated and this index is multiplied by the development cost in Austria. The development cost is a one-off cost that is paid in the beginning of the project (i.e. base year). The development cost for the city of Thessaloniki is 60.000€.

Operations and maintenance costs correspond to costs for hosting the server application. These costs mainly depend on the amount of data generated from the distributed traffic messages and the logging activities carried out for the evaluation purposes. For Vienna's pilot site these costs have been estimated to be 40€ per month, which corresponds to an annual cost of 480€. Adjusted for current Greek economic conditions according to the aforementioned methodology utilizing the GDP per capita (PPP) of each country the annual operation and maintenance costs for the implementation of the system in Thessaloniki are 288€. The annual operation and maintenance costs of the system remain constant throughout the project's lifetime. However, future costs have to be discounted to present values, so that the benefit-cost ratio can be estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values along with the initial development cost are shown in Table 10.

Table 10: Detailed cost description of the implementation of a C-ITS system in Thessaloniki.

Costs	2013	2014	2015	2016	2017	2018	2019	2020
Development (€)	60.000	0	0	0	0	0	0	0
Operation & Maintenance (€)	0	288	288	288	288	288	288	288
Total (€)	60.000	288	288	288	288	288	288	288
Discounted Total (€)	60.000	269	252	235	220	205	192	179
Total Cost (€) (Present Value)								61.552

3.1.2. Analysis of Benefits

According to project activity 6.1, a prospective implementation of Vienna's C-ITS system in Thessaloniki is going to yield reduction in CO2 emissions produced by the transport sector and in the number of accidents occurring in the city's road network. These impacts have been explicitly quantified in the aforementioned activity. Apart from these direct benefits, the reduction of the number of accidents will also result in the mitigation of non-recurring congestion. Thus, travel time and fuel consumption savings occur as well.

Accidents are reduced at most by 1 per year. Thus, it is assumed that for some years (i.e. 2015, 2017, and 2018) the system will have no effect on traffic operations. Travel time, emissions and fuel consumption savings do not occur for years that accidents are not reduced. For the rest of the years pertaining to the project evaluation only traffic accidents involving slight injuries are expected to be reduced by one per year.

Travel time savings have not been identified as a direct benefit of the C-ITS system, and therefore, have not been quantified in project activity 6.1. The assumed reduction of annual vehicle-hours travelled in the city of Thessaloniki due to the system installation is 0.01%. Moreover, the system deployed in Vienna services an area of the city which is far smaller than the area of the city of Thessaloniki. Thus, the transferrable impacts should not be applied on the total vehicle-hours travelled in the city of Thessaloniki. An adjustment is necessary that accounts for the extent of the area the system affects. The area corresponding to the road network that the system has been deployed in Vienna has been measured through Google Maps. This area has been divided by the area of the city of Thessaloniki and the resulting index is multiplied by the total vehicle-hours travelled in the city to derive those that correspond to the area of interest. The total estimated benefit in vehicle-hours can be obtained by multiplying the annual vehicle-hours travelled in the city of Thessaloniki by the assumed transferrable impact factor and the adjustment factor that accounts for the extent of the deployed area. The estimated benefit is 676 vehicle-hours per year. This benefit remains constant throughout the project's lifetime.

CO_2 emissions statistics are only available at a national level for Greece. The estimation of the portion of CO_2 emissions that is generated from the vehicle fleet travelling on the road network of the city of Thessaloniki will be based on the number of annual vehicle-kilometres travelled in the city of Thessaloniki compared to those travelled on the national road network. The ratio of the annual vehicle-kilometres travelled in the city of Thessaloniki to the total annual vehicle-kilometres travelled in Greece is multiplied by the annual national CO_2 emissions generated from the transport network to estimate the CO_2 emissions that correspond to the city of Thessaloniki (i.e. 2269 kilo-tons annually). The reduction of annual CO_2 emissions in the city of Thessaloniki due to the system installation is 0.01%. Accounting also for the fact that the pilot site area is far smaller than the city of Thessaloniki, the benefit from CO_2 emissions reduction has to be adjusted accordingly in order to reflect this difference. This adjustment is analogous to that made with respect to travel time savings. It is estimated that 16 tons of CO_2 less are going to be emitted annually after the system installation. This benefit remains constant during the whole project lifetime.

Like CO_2 emissions statistics, fuel consumption statistics are only available at a national level for Greece. Thus, the intermediate calculation steps to estimate the annual reduction of consumed fuel (i.e. in litres/year) due to the system deployment are exactly the same with those described previously for the estimation of the CO_2 emissions reduction. Considering that the market split regarding fuel type consumption is approximately 70% petrol and 30% diesel, the annual reductions in petrol and diesel consumption are 3712 litres and 1590 litres respectively. These benefits remain constant during the project's lifetime. The quantified travel time, emissions and fuel consumption savings are presented in Table 11.

Table 11: Benefits from a C-ITS system implementation in Thessaloniki.

Travel Time Savings (in vehicle-hours/Year)	676
CO_2 Emissions Savings (in kilo-tons/Year)	16
Petrol Consumption Savings (in L/Year)	3712

Diesel Consumption Savings (in L/Year)	1590

The monetization of the quantified benefits is based on the determination of all the relevant cost factors for each benefit category. This task has been facilitated with the use of the cost factors provided in the HEATCO report. This report was finalized in 2006 and the estimated cost factors represent 2002 socio-economic conditions across EU. Therefore, it is essential that the cost factors are converted to present values (i.e. 2014 estimates), so that the projected benefits can be finally monetized. The conversion is done utilizing the present value formula (i.e. Equation 1) and the growth rate is equal to the annual growth rate of GDP per capita of the corresponding country that the deployment of the ITS is taking place. Detailed information regarding the annual growth rate of GDP per capita of each country can be found through the website of The World Bank. The annual growth rate of GDP per capita in Greece between 2002 and 2013 is presented in Table 12.

Table 12: Annual Growth Rate of GDP/capita in Greece since 2002

Year	Annual Growth Rate of GDP/capita
2002	0,031
2003	0,056
2004	0,040
2005	0,019
2006	0,052
2007	0,032
2008	-0,004
2009	-0,031
2010	-0,047
2011	-0,069
2012	-0,067
2013	-0,033

The value of travel time per year in Greece since 2002 is estimated according to the relevant annual growth factor of GDP per capita and is presented in Table 13. The cost factors pertaining to each accident category (i.e. fatality, severe injury, or slight injury) in Greece since 2002 are also estimated accordingly and presented in Table 14. The cost factor regarding CO2 emissions in Greece for 2014 can be directly obtained from the HEATCO report. For the estimation of the economic benefit from fuel savings current (i.e. 2014) petrol and diesel market prices are used. As it has been already mentioned, the identified benefits from a potential implementation of Vienna's C-ITS system in Thessaloniki are accidents reduction, travel time, CO_2 emissions and fuel consumption savings. The relevant cost factors for these benefits are presented in Table 15. The values of the cost factors are considered constant throughout the project lifetime, so that benefits are not overestimated.

Table 13: Value of travel time per year in Greece since 2002

Year	Value of Travel Time (€)
2002	19,42
2003	20,51
2004	21,33
2005	21,73
2006	22,86
2007	23,59
2008	23,50
2009	22,77
2010	21,70
2011	20,20
2012	18,85
2013	18,23

Table 14: Cost per accident category in Greece since 2002

Year	Fatality (€)	Severe Injury (€)	Slight Injury (€)
2002	836000	109500	8400
2003	882816	115632	8870
2004	918129	120257	9225
2005	935573	122542	9400
2006	984223	128914	9889
2007	1015718	133040	10206
2008	1011655	132507	10165
2009	980294	128400	9850
2010	934220	122365	9387
2011	869759	113922	8739
2012	811485	106289	8154
2013	784706	102781	7885

Table 15: Cost factors for the Greek system

Value of Travel Time (€/hour)	18,23
Value of Accident (€/slight injury)	7885

Value of CO_2 Emissions (€/ton)	26
Value of Petrol Fuel (€/litre)	1,55
Value of Diesel Fuel (€/litre)	1,23

Finally, future benefits have to be discounted to present values, so that the benefit-cost ratio can be finally estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values are shown per benefit category in Tables 16, 17, 18 and 19. The total present value of the benefits amount to 110.090€ and the benefit-cost ratio is 1,79.

Table 16: Travel time savings (Cooperative Traffic Management)

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of Vehicle-hours	676	0	676	0	0	676	676
Value of Travel Time (€/hour)	18,23	18,23	18,23	18,23	18,23	18,23	18,23
Travel time savings (€)	12.323	0	12.323	0	0	12.323	12.323
Discounted Values (€)	11.517	0	10.059	0	0	8.211	7.674
Total Benefit (€) (Present Value)							37.461

Table 17: Savings generated from accidents reduction (Cooperative Traffic Management).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of slight injuries	1	0	1	0	0	1	1
Cost factor (€/slight injury)	7.885	7.885	7.885	7.885	7.885	7.885	7.885
Correction factor	2,00	2,00	2,00	2,00	2,00	2,00	2,00
Savings (€)	15.769	0	15.769	0	0	15.769	15.769
Discounted Values (€)	14.738	0	12.872	0	0	10.508	9.820
Total Benefit (€) (Present Value)							47.938

Table 18: Savings generated from CO2 emissions reduction (Cooperative Traffic Management).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of CO2 emissions (tons)	15,88	0	15,88	0	0	15,88	15,88

Cost factor (€/ton)	26,00	26,00	26,00	26,00	26,00	26,00	26,00
Savings (€)	413	0	413	0	0	413	413
Discounted Values (€)	386	0	337	0	0	275	257
Total Benefit (€) (Present Value)					1.255		

Table 19: Savings generated from fuel consumption reduction (Cooperative Traffic Management).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of consumed Petrol (litters)	3.712	0	3.712	0	0	3.712	3.712
Price of petrol (€/litter)	1,55	1,55	1,55	1,55	1,55	1,55	1,55
Savings (€)	5.754	0	5.754	0	0	5.754	5.754
Reduction of consumed Diesel (litters)	1.590	0	1.590	0	0	1.590	1.590
Price of diesel (€/litter)	1,23	1,23	1,23	1,23	1,23	1,23	1,23
Savings (€)	1.956	0	1.956	0	0	1.956	1.956
Total Savings from Reduction of Fuel Consumption (€)	7.709	0	7.709	0	0	7.709	7.709
Discounted Values (€)	7.205	0	6.293	0	0	5.137	4.800
Total Benefit (€) (Present Value)							23.436

4. COST-BENEFIT ANALYSIS OF ITS DEPLOYMENT FOR ROAD NETWORKS IN GREECE

4.1. Introduction

The feasibility of the implementation of a route planning engine in the city of Thessaloniki, which is highly specialized to serve the public transport needs of cyclists is assessed in economic terms. This system has been already installed and piloted in the City of Budapest within the context of the SEE-ITS project. The evaluation of the system's operation and performance has been presented in project activity 5.3. The transferrable impacts of Budapest's pilot system to Thessaloniki's road transport network operations have been determined and quantified in project activities 5.3 and 6.1. The CBA presented subsequently is based on the information provided in the aforementioned activities.

4.1.1. Analysis of Costs

Initially, the total cost of the system, throughout the project's evaluation lifespan (i.e. 7 years), has to be estimated. This cost is comprised of the development, operations and maintenance costs.

The development cost corresponds to the building of the intermodal route planning application. This cost was 33.200 € for Budapest's pilot site. For the implementation of the same system in Thessaloniki the development cost has to be adjusted in order to be representative of current Greek economic conditions. This adjustment is based on the GDP per capita (PPP) of Austria and Greece during the base year of the project evaluation lifecycle. The ratio of the Greek GDP per capita (PPP) to Austria's GDP per capita (PPP) is estimated and this index is multiplied by the development cost in Austria. The development cost is a one-off cost that is paid in the beginning of the project. The development cost for the city of Thessaloniki is 37.848 €.

Operation and maintenance costs correspond to costs for editing and testing the application's database, answering forum questions and operating a helpdesk. For Budapest's pilot site these costs have been estimated to be 110€ per month, which corresponds to an annual cost of 1320€. Adjusted for current Greek economic conditions according to the aforementioned methodology utilizing the GDP per capita (PPP) of each country the annual operation and maintenance costs for the implementation of the system in Thessaloniki are 1505 €. The annual operation and maintenance costs of the system remain constant throughout the project's lifetime. However, future costs have to be discounted to present values, so that the benefit-cost ratio can be finally estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values along with the initial development cost are shown in Table 20.

Table 20: Detailed cost description of the implementation of a route planning system in Thessaloniki.

Costs (€)	2013	2014	2015	2016	2017	2018	2019	2020
Development (€)	37.848	0	0	0	0	0	0	0
Operation & Maintenance (€)	0	1505	1505	1505	1505	1505	1505	1505
Total (€)	37.848	1505	1505	1505	1505	1505	1505	1505
Discounted Total (€)	37.848	1406	1314	1228	1148	1072	1002	937
Total Cost (€) (Present Value)								45.958

4.1.2. Analysis of Benefits

According to project activity 6.1, a prospective implementation of Budapest's intermodal route planning engine in Thessaloniki is going to yield reduction in the total number of vehicle-kilometres travelled in the city. This impact has been explicitly quantified in the aforementioned activity. Apart from this direct benefit of the application deployment, the reduction of the vehicle-kilometres travelled will also result in travel time savings, CO2 emissions and fuel consumption savings.

The application of the route planning engine is going to yield a daily reduction of 8.170 vehicle-kilometres in the city of Thessaloniki, given the results of project activity 6.1. This is translated in an annual reduction of 2.982.050 vehicle-kilometres. Since the average traffic speed on Thessaloniki's road network is approximately 30 km/hr, the annual vehicle-kilometres reduction corresponds to 99.402 vehicle-hours travel time savings. However, Thessaloniki's bicycle network has been developed in a very small geographical extent and the number of daily bicycle users is insignificant compared to other mode users. Thus, the penetration rate of the application is assumed to be very small (i.e. 1%) among the daily travellers in the city of Thessaloniki. The estimated annual travel time savings are adjusted accordingly. The estimated benefit per year is 994 vehicle-hours. This benefit remains constant throughout the project lifetime.

CO2 emissions statistics are only available at a national level for Greece. The estimation of the portion of CO2 emissions that is generated from the vehicle fleet travelling on the road network of the city of Thessaloniki will be based on the number of annual vehicle-kilometres travelled in the city of Thessaloniki compared to those travelled on the national road network. The ratio of the annual vehicle-kilometres travelled in the city of Thessaloniki to the total annual vehicle-kilometres travelled in Greece is multiplied by the annual national CO2 emissions generated from the transport network to estimate the CO2 emissions that correspond to the city of Thessaloniki (i.e. 2269 kilo-tons annually). The reduction of annual CO2 emissions in the city of Thessaloniki due to the system installation is 0.1%. Accounting also for the fact that the penetration rate of the route assistance application is 1%, the benefit from CO2 emissions reduction has to be adjusted accordingly. This adjustment is analogous to that made for the travel time savings. It is estimated that 23 tons of CO2 less are going to be emitted annually after the system installation. This benefit remains constant during the project lifetime.

Like CO2 emissions statistics, fuel consumption statistics are only available at a national level for Greece. Thus, the intermediate calculation steps to estimate the annual reduction of consumed fuel (i.e. in litres/year) due to the system deployment are exactly the same with those described previously for the estimation of the CO2 emissions reduction. Considering that the market split regarding fuel type consumption is approximately 70% petrol and 30% diesel, the annual reductions in petrol and diesel consumption are 5303 litres and 2272 litres respectively. These benefits remain constant during the project lifetime. The quantified travel time, emissions and fuel consumption savings are presented in Table 21.

Table 21: Benefits from a route planning system deployment in Thessaloniki.

Travel Time Savings (in vehicle-hours/Year)	994
CO2 Emissions Savings (in kilo-tons/Year)	23
Petrol Consumption Savings (in litres/Year)	5303
Diesel Consumption Savings (in litres/Year)	2272

The monetization of the quantified benefits is based on the determination of all the relevant cost factors for each benefit category. This task has been facilitated with the use of the cost factors provided in the HEATCO report. This report was finalized in 2006 and the estimated cost factors represent 2002 socio-economic conditions across EU. Therefore, it is essential that the cost factors are converted to present values (i.e. 2014 estimates), so that the projected benefits can be monetized. The conversion is done utilizing the present value formula (i.e. Equation 1) and the growth rate is equal to the annual growth rate of GDP per capita of the corresponding country that the deployment of the ITS is taking place. Detailed information regarding the annual growth rate of GDP per capita of each country can be found through the website of The World Bank. The annual growth rate of GDP per capita in Greece since 2002 is presented in Table 22.

Table 22: Annual Growth Rate of GDP/capita in Greece since 2002

Year	Annual Growth Rate of GDP/capita
2002	0,031
2003	0,056
2004	0,040
2005	0,019
2006	0,052
2007	0,032
2008	-0,004
2009	-0,031
2010	-0,047
2011	-0,069
2012	-0,067
2013	-0,033

The value of travel time per year in Greece since 2002 is estimated according to the relevant annual growth factor of GDP per capita and is presented in Table 23. The cost factors pertaining to each accident category (i.e. fatality, severe injury, or slight injury) for the same years are also estimated accordingly and presented in Table 24. The cost factor regarding CO2 emissions in Greece for 2014 can be directly obtained from the HEATCO report. For the estimation of the economic benefit from fuel savings current (i.e. 2014) petrol and diesel market prices are used. As it has been already mentioned, the identified benefits from a potential implementation of Budapest's ITS system in Thessaloniki are vehicle-kilometres reduction, travel time, CO2 emissions and fuel consumption savings. The relevant cost factors for the latter three benefits are presented in Table 25. The values of the cost factors are considered constant throughout the project lifetime, so that benefits are not overestimated.

Table 23: Value of travel time per year in Greece since 2002

Year	Value of Travel Time (€)
2002	19,42
2003	20,51

2004	21,33
2005	21,73
2006	22,86
2007	23,59
2008	23,50
2009	22,77
2010	21,70
2011	20,20
2012	18,85
2013	18,23

Table 24: Cost per accident category in Greece since 2002

Year	Fatality (€)	Severe Injury (€)	Slight Injury (€)
2002	836000	109500	8400
2003	882816	115632	8870
2004	918129	120257	9225
2005	935573	122542	9400
2006	984223	128914	9889
2007	1015718	133040	10206
2008	1011655	132507	10165
2009	980294	128400	9850
2010	934220	122365	9387
2011	869759	113922	8739
2012	811485	106289	8154
2013	784706	102781	7885

Table 25: Cost factors for the Greek system

Value of Travel Time (€/hour)	18,23
Value of Accident (€/slight injury)	7885
Value of CO_2 Emissions (€/ton)	26
Value of Petrol Fuel (€/litre)	1,55
Value of Diesel Fuel (€/litre)	1,23

Finally, future benefits have to be discounted to present values, so that the benefit-cost ratio can be finally estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values are shown per benefit category in Table 26, 27, and 28. The total present value of the benefits amount to 160.196 € and the benefit-cost ratio is 3,49.

Table 26: Travel time savings (ITS-Route Planning Engine)

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of Vehicle-hours	994	994	994	994	994	994	994
Value of Travel Time (€/hour)	18,23	18,23	18,23	18,23	18,23	18,23	18,23
Travel time savings (€)	18.119	18.119	18.119	18.119	18.119	18.119	18.119
Discounted Values (€)	16.934	15.826	14.791	13.823	12.919	12.074	11.284
Total Benefit (€) (Present Value)							97.651

Table 27: Savings generated from CO2 emissions reduction (ITS-Route Planning Engine).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of CO2 emissions (tons)	22,68	22,68	22,68	22,68	22,68	22,68	22,68
Cost factor (€/ton)	26,00	26,00	26,00	26,00	26,00	26,00	26,00
Savings (€)	590	590	590	590	590	590	590
Discounted Values (€)	551	525	482	450	421	393	367
Total Benefit (€) (Present Value)							3.179

Table 28: Savings generated from fuel consumption reduction (ITS-Route Planning Engine).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of consumed Petrol (litres)	5.303	5.303	5.303	5.303	5.303	5.303	5.303
Price of petrol (€/litre)	1,55	1,55	1,55	1,55	1,55	1,55	1,55
Savings (€)	8.220	8.220	8.220	8.220	8.220	8.220	8.220
Reduction of consumed Diesel (litres)	2.273	2.273	2.273	2.273	2.273	2.273	2.273
Price of diesel (€/litre)	1,23	1,23	1,23	1,23	1,23	1,23	1,23
Savings (€)	2.796	2.796	2.796	2.796	2.796	2.796	2.796
Total Savings from Reduction of Fuel Consumption (€)	11.016	11.016	11.016	11.016	11.016	11.016	11.016
Discounted Values (€)	10.295	9.621	8.991	8.403	7.853	7.340	6.860
Total Benefit (€) (Present Value)							59.366

5. COST-BENEFIT ANALYSIS OF OPTIMAL USE OF TRAFFIC AND TRAVEL DATA IN GREECE

5.1. Introduction

The feasibility of the installation and implementation of a Bluetooth Information System along Thessaloniki's ring road is assessed in economic terms. This system has been already installed and piloted in the City of Sofia, Bulgaria within the context of the SEE-ITS project. The evaluation of the system's operation and performance has been presented in project activity 5.3. The potential transferrable impacts of Sofia's pilot system to Thessaloniki's road transport network operations have been determined and quantified in project activities 5.3 and 6.1. The CBA presented subsequently is based on the information provided in the aforementioned activities.

5.1.1. Analysis of Costs

Initially, the total cost of the system, throughout the project's evaluation lifespan (i.e. 7 years), has to be estimated. This cost is comprised of the development, operation and maintenance costs. The development cost corresponds to the purchase and installation of 20 Bluetooth road-side devices along the highway corridor. The development cost is a one-off cost that is paid in the beginning of the project (i.e. base year). The development cost for the city of Thessaloniki is 45.372 €.

Operational costs correspond to direct costs such as telecommunications costs, power supply costs, salaries of the necessary personnel plus other indirect costs. Maintenance costs include costs for labour and parts for the maintenance and repair of the Bluetooth devices. Annual operation and maintenance costs for the implementation of the system in Thessaloniki are 3048 €. The annual operation and maintenance costs of the system remain constant throughout the project's lifetime. However, future costs have to be discounted to present values, so that the benefit-cost ratio can be finally estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values along with the initial development cost are shown in Table 29.

Table 29: Detailed cost description of the implementation of a Bluetooth information system in Thessaloniki.

Costs	2013	2014	2015	2016	2017	2018	2019	2020
Development (€)	45.372	0	0	0	0	0	0	0
Operation & Maintenance (€)	0	3048	3048	3048	3048	3048	3048	3048
Total (€)	45.372	3048	3048	3048	3048	3048	3048	3048
Discounted Total (€)	45.372	2849	2662	2488	2325	2173	2031	1898
Total Cost (€) (Present Value)								61.799

5.1.2. Analysis of Benefits

According to project activity 6.1, a prospective implementation of Sofia's Bluetooth information system (BTiS) along Thessaloniki's ring road is going to yield travel time, CO2 emissions and fuel consumption savings. These impacts have been explicitly quantified in the aforementioned activity.

Approximately 10,57 million vehicle-kilometres are travelled annually along Thessaloniki's ring road. The average traffic flow speed on this road axis is 90km/hr. Thus, the annual vehicle-kilometres travelled can be converted to 117.512 vehicle-hours. However, according to project activity 6.1, the application of the system is going to reduce the annual vehicle-hours travelled along Thessaloniki's ring road by 0,05%. Thus, the estimated benefit per year is 59 vehicle-hours. This benefit remains constant throughout the project's lifetime.

CO2 emissions statistics are only available at a national level for Greece. The estimation of the portion of CO2 emissions that is generated from vehicular traffic travelling along Thessaloniki's ring road will be based on the number of annual vehicle-kilometres travelled along this highway corridor compared to those travelled on the national road network. The ratio of the annual vehicle-kilometres travelled along Thessaloniki's ring road to the total annual vehicle-kilometres travelled in Greece is multiplied by the annual national CO2 emissions generated from the transport network to estimate the CO2 emissions that correspond to the city of Thessaloniki (i.e. 8 kilo-tons annually). The reduction of annual CO2 emissions in the city of Thessaloniki due to the system installation is 0.05%. This adjustment is analogous to that made for travel time savings. It is estimated that 4 tons of CO2 less are going to be emitted annually after the system installation. This benefit remains constant during the project's lifetime.

Like CO2 emissions statistics, fuel consumption statistics are only available at a national level for Greece. Thus, the intermediate calculation steps to estimate the annual reduction of consumed fuel (i.e. in litres/year) due to the system deployment are exactly the same with those described previously for the estimation of the CO2 emissions reduction. Considering that the market split regarding fuel type consumption is approximately 70% petrol and 30% diesel, the annual reductions in petrol and diesel consumption are 941 litres and 403 litres respectively. These benefits remain constant during the project's lifetime. The quantified travel time, emissions and fuel consumption savings are presented in Table 30.

Table 30: Benefits from a BTiS implementation in Thessaloniki.

Travel Time Savings (in vehicle-hours/year)	59
CO2 Emissions Savings (in tons/year)	4
Petrol Consumption Savings (in Lt/year)	941
Diesel Consumption Savings (in Lt/year)	403

The monetization of the quantified benefits is based on the determination of all the relevant cost factors for each benefit category. This task has been facilitated with the use of the cost factors provided in the HEATCO report. This report was finalized in 2006 and the estimated cost factors represent 2002 socio-economic conditions across EU. Therefore, it is essential that the cost factors are converted to present values (i.e. 2014 estimates), so that the projected benefits can be monetized. The conversion is done utilizing the present value formula (i.e. Equation 1) and the growth rate is equal to the annual growth rate of GDP per capita of the corresponding country that the deployment of the ITS is taking place. Detailed information regarding the annual growth rate of GDP per capita of each country can be found through the website of The World Bank. The annual growth rate of GDP per capita in Greece since 2002 is presented in Table 31.

Table 31: Annual Growth Rate of GDP/capita in Greece since 2002

Year	Annual Growth Rate of GDP/capita
2002	0,031
2003	0,056
2004	0,040
2005	0,019
2006	0,052
2007	0,032
2008	-0,004
2009	-0,031

2010	-0,047
2011	-0,069
2012	-0,067
2013	-0,033

The value of travel time per year in Greece since 2002 is estimated according to the relevant annual growth factor of GDP per capita and is presented in Table 32. The cost factor regarding CO2 emissions in Greece for 2014 can be directly obtained from the HEATCO report. For the estimation of the economic benefit from fuel savings current (i.e. 2014) petrol and diesel market prices are used. As it has been already mentioned, the identified benefits from a potential implementation of Sofia's Bluetooth information system in Thessaloniki are travel time, CO2 emissions and fuel consumption savings. The relevant cost factors for the latter three benefits are presented in Table 33. The values of the cost factors are considered constant throughout the project lifetime, so that benefits are not overestimated.

Table 32: Value of travel time per year in Greece since 2002

Year	Value of Travel Time (€)
2002	19,42
2003	20,51
2004	21,33
2005	21,73
2006	22,86
2007	23,59
2008	23,50
2009	22,77
2010	21,70
2011	20,20
2012	18,85
2013	18,23

Table 33: Cost factors for the Greek system

Value of Travel Time (€/hour)	18,23
Value of CO_2 Emissions (€/tonne)	26
Value of Petrol Fuel (€/litre)	1,55
Value of Diesel Fuel (€/litre)	1,23

Finally, future benefits have to be discounted to present values, so that the benefit-cost ratio can be finally estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values are shown per benefit category in Table 34, 35, and 36. The total present value of the benefits amount to 16.865 € and the benefit-cost ratio is 0,27.

Table 34: Travel time savings (Bluetooth Information System)

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of Vehicle-hours	59	59	59	59	59	59	59
Value of Travel Time (€/hour)	18,23	18,23	18,23	18,23	18,23	18,23	18,23
Travel time savings (€)	1.071	1.071	1.071	1.071	1.071	1.071	1.071
Discounted Values (€)	2.849	2.662	2.488	2.325	2.173	2.031	1.898
Total Benefit (€) (Present Value)							97.651

Table 35: Savings generated from CO2 emissions reduction (Bluetooth Information System).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of CO2 emissions (tons)	4,0	4,0	4,0	4,0	4,0	4,0	4,0
Cost factor (€/ton)	26,00	26,00	26,00	26,00	26,00	26,00	26,00
Savings (€)	104	104	104	104	104	104	104
Discounted Values (€)	97	91	85	79	74	69	65
Total Benefit (€) (Present Value)							560

Table 36: Savings generated from fuel consumption reduction (Bluetooth Information System).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of consumed Petrol (litters)	941	941	941	941	941	941	941
Price of petrol (€/litter)	1,55	1,55	1,55	1,55	1,55	1,55	1,55
Savings (€)	1458	1458	1458	1458	1458	1458	1458
Reduction of consumed Diesel (litters)	403	403	403	403	403	403	403
Price of diesel (€/litter)	1,23	1,23	1,23	1,23	1,23	1,23	1,23
Savings (€)	496	496	496	496	496	496	496
Total Savings from	1954	1954	1954	1954	1954	1954	1954

Reduction of Fuel Consumption (€)							
Discounted Values (€)	1826	1707	1595	1491	1393	1302	1217
Total Benefit (€) (Present Value)							10.532

6. COST-BENEFIT ANALYSIS OF DANGEROUS GOODS MONITORING IN GREECE

6.1. Introduction

The feasibility of the development of a management centre for the real-time monitoring of the transportation of dangerous goods along Thessaloniki's peripheral ring-road is assessed in economic terms. This system has been already installed and piloted in Emilia Romagna, Italy within the context of the SEE-ITS project. The evaluation of the system's operation and performance has been presented in project activity 5.3. The potential transferrable impacts of Italy's pilot system to Thessaloniki's ring road traffic operations have been determined and quantified in project activities 5.3 and 6.1. The CBA presented subsequently is based on the information provided in the aforementioned activities.

6.1.1. Analysis of Costs

Initially, the total cost of the system, throughout the project's evaluation lifespan (i.e. 7 years), has to be estimated. This cost is comprised of the development, operation and maintenance costs.

The development cost corresponds to the purchase and installation of 5 road-side devices, the cost of the necessary equipment for the management centre, the cost of the diagnostic system, and the cost of the required software for the operation of the systems. The development cost is a one-off cost that is paid in the beginning of the project (i.e. base year). The development cost for the city of Thessaloniki is 130.000 €.

Operational costs correspond to the annual salary of the Operation Manager, while maintenance costs correspond to the salary of the technician (i.e. part-time job) and the organization of the maintenance activities. However, the operational and maintenance costs have to be adjusted in order to be representative of the current Greek economic conditions. This adjustment is based on the GDP per capita (PPP) of Italy and Greece during the base year of the project's evaluation lifecycle. The ratio of the Greek GDP per capita (PPP) to Italy's GDP per capita (PPP) is estimated and this index is multiplied by the operation and maintenance costs in Italy. For Italy's pilot site these costs have been estimated to be 30.500 € per year. Adjusted for current Greek economic conditions annual operation and maintenance costs for the implementation of the system in Thessaloniki are 22.875 €. The annual operation and maintenance costs of the system remain constant throughout the project's lifetime. However, future costs have to be discounted to present values, so that the benefit-cost ratio can be estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values along with the initial development cost are shown in Table 37.

Table 37: Detailed cost description of the implementation of a dangerous goods monitoring system in Thessaloniki.

Costs (€)	2013	2014	2015	2016	2017	2018	2019	2020
Development (€)	130.000	0	0	0	0	0	0	0
Operation & Maintenance (€)	0 €	22.875	22.875	22.875	22.875	22.875	22.875	22.875
Total (€)	130.000	22.875	22.875	22.875	22.875	22.875	22.875	22.875
Discounted Total (€)	130.000	21.379	19980	18673	17.451	16.310	15.243	15.245
Total Cost (€) (Present Value)								253.280

6.1.2. Analysis of Benefits

According to project activity 6.1, a prospective implementation of Italy's dangerous goods monitoring system along Thessaloniki's ring road is going to yield reduction in the number of accidents occurring on the respective road segments. This impact has been explicitly quantified in the aforementioned activity. No indirect impacts of this system implementation have been identified. Accidents are going to be reduced by 1 per year if the system is deployed along the ring road, based on the findings of project activity 6.1. The system is capable of reducing accidents involving slight and severe injuries.

The monetization of the quantified benefits is based on the determination of all the relevant cost factors for each benefit category. This task has been facilitated with the use of the cost factors provided in the HEATCO report. This report was finalized in 2006 and the estimated cost factors represent 2002 socio-economic conditions across EU. Therefore, it is essential that the cost factors are converted to present values (i.e. 2014 estimates), so that the projected benefits can be monetized. The conversion is done utilizing the present value formula (i.e. Equation 1) and the growth rate is equal to the annual growth rate of GDP per capita of the corresponding country that the deployment of the ITS is taking place. Detailed information regarding the annual growth rate of GDP per capita of each country can be found through the website of The World Bank. The annual growth rate of GDP per capita in Greece since 2002 is presented in Table 38.

Table 38: Annual Growth Rate of GDP/capita in Greece since 2002

Year	Annual Growth Rate of GDP/capita
2002	0,031
2003	0,056
2004	0,040
2005	0,019
2006	0,052
2007	0,032
2008	-0,004
2009	-0,031
2010	-0,047
2011	-0,069
2012	-0,067
2013	-0,033

The annual cost factors pertaining to each accident category (i.e. fatality, severe injury, or slight injury) for Greece since 2002 are estimated according to the relevant annual growth factor of GDP per capita and are presented in Table 39. As it has been already mentioned, the identified benefit from a potential implementation of Italy's dangerous goods monitoring system in Thessaloniki is accidents reduction. The values of the cost factors are considered constant throughout the project lifetime, so that benefits are not overestimated.

Table 39: Cost per accident category in Greece since 2002

Year	Fatality (€)	Severe Injury (€)	Slight Injury (€)
2002	836000	109500	8400
2003	882816	115632	8870
2004	918129	120257	9225
2005	935573	122542	9400
2006	984223	128914	9889
2007	1015718	133040	10206
2008	1011655	132507	10165
2009	980294	128400	9850
2010	934220	122365	9387
2011	869759	113922	8739
2012	811485	106289	8154
2013	784706	102781	7885

Finally, future benefits have to be discounted to present values, so that the benefit-cost ratio can be finally estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values are shown per benefit category in Tables 40, and 41. The total present value of the benefits amount to 349.771 € and the benefit-cost ratio is 1,38.

Table 40: Savings generated from accidents reduction (severe injuries).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of slight injuries	0	1	0	1	1	0	0
Cost factor (€/slight injury)	102.781	102.781	102.781	102.781	102.781	102.781	102.781
Correction factor	1,25	1,25	1,25	1,25	1,25	1,25	1,25
Savings (€)	0	128.477	0	128.477	128.477	0	0
Discounted Values (€)	0	112.217	0	98.014	91.602	0	0
Total Benefit (€) (Present Value)							301.833

Table 41: Savings generated from accidents reduction (slight injuries).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of slight injuries	1	0	1	0	0	1	1
Cost factor (€/slight injury)	7.885	7.885	7.885	7.885	7.885	7.885	7.885
Correction factor	2,00	2,00	2,00	2,00	2,00	2,00	2,00
Savings (€)	15.769	0	15.769	0	0	15769	15.769
Discounted Values (€)	14.738	0	12.872	0	0	10.508	9.820
Total Benefit (€) (Present Value)							47.938

7. COST-BENEFIT ANALYSIS OF INTERMODAL TRAVEL PLANNING SERVICES IN GREECE

The feasibility of the installation and implementation of an Intermodal Travel Planning System along Athens-Thessaloniki national road is assessed in economic terms. This system has been already installed and piloted in Romania within the context of the SEE-ITS project. The evaluation of the system's operation and performance has been presented in project activity 5.3. The potential transferrable impacts of Romania's pilot system to the Athens-Thessaloniki national road traffic operations have been determined and quantified in project activities 5.3 and 6.1. The CBA presented subsequently is based on the information provided in the aforementioned activities.

7.1.1. Analysis of Costs

Initially, the total cost of the system, throughout the project's evaluation lifespan (i.e. 7 years), has to be estimated. This cost is comprised of the development, operation and maintenance costs. The development cost corresponds to the building of the overall software for the travel planning application. The development cost is a one-off cost that is paid in the beginning of the project (i.e. base year). The development cost for Greece is 63.340 €.

Operation costs correspond to cloud storage, web hosting service, and personnel costs in order to ensure the proper operation of the software application. Maintenance costs include costs for software (i.e. OS) updates, as well as map and transport graph updates. Annual operation and maintenance costs for the implementation of the system in Greece are 11.753 €. The annual operation and maintenance costs of the system remain constant throughout the project's lifetime. However, future costs have to be discounted to present values, so that the benefit-cost ratio can be finally estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values along with the initial development cost are shown in Table 42.

Table 42: Detailed cost description of the implementation of an intermodal travel planning service in Thessaloniki.

Costs	2013	2014	2015	2016	2017	2018	2019	2020
Development (€)	29.200	0	0	0	0	0	0	0
Operation &			11.753	11.753	11.753	11.753	11.753	11.753

Maintenance (€)	0	11.753						
Total (€)	29.200	11.753	11.753	11.753	11.753	11.753	11.753	11.753
Discounted Total (€)	29.200	10.984	10.266	9.594	8.966	8.380	7.832	7.319
Total Cost (€) (Present Value)								92.540

7.1.2. Analysis of Benefits

According to project activity 6.1, a prospective implementation of Romania's intermodal travel planning system along the Athens-Thessaloniki national road is going to yield travel time, CO2 emissions and fuel consumption savings. These impacts have been explicitly quantified in the aforementioned activity.

Approximately 1.888 million vehicle-kilometres are travelled annually along the Athens-Thessaloniki national road. The average traffic flow speed on this road axis is 90km/hr. Thus, the annual vehicle-kilometres travelled can be converted to 20.977.778 vehicle-hours. According to project activity 6.1, the application of the system is going to reduce the annual vehicle-hours travelled along the Athens-Thessaloniki national road by 5,00%. However, the impacts recorded in the Romanian pilot site are not fully transferrable to Greece, since the architecture of the designed system account only for the particularities of the transportation network in Romania (i.e. concurrent existence of road network, railway network, and waterways). In Greece these options are not available, and consequently the penetration rate of the application is expected to be low (i.e. 1,00%). Thus, the benefit is adjusted accordingly and is estimated 10.489 vehicle-hours per year. This benefit remains constant throughout the project's lifetime.

CO2 emissions statistics are only available at a national level for Greece. The estimation of the portion of CO2 emissions that is generated from vehicular traffic travelling along the Athens-Thessaloniki national road will be based on the number of annual vehicle-kilometres travelled along this highway corridor compared to those travelled on the national road network. The ratio of the annual vehicle-kilometres travelled along the Athens-Thessaloniki national road to the total annual vehicle-kilometres travelled in Greece is multiplied by the annual national CO2 emissions generated from the transport network to estimate the CO2 emissions that correspond to the city of Thessaloniki (i.e. 8 kilo-tons annually). The reduction of annual CO2 emissions in the city of Thessaloniki due to the system installation is 1.00%. This adjustment is analogous to that made for travel time savings. Given that the penetration rate of the system is going to be 1,00%., it is estimated that 144 tons of CO2 less are going to be emitted annually after the system installation. This benefit remains constant during the project's lifetime.

Like CO2 emissions statistics, fuel consumption statistics are only available at a national level for Greece. Thus, the intermediate calculation steps to estimate the annual reduction of consumed fuel (i.e. in litres/year) due to the system deployment are exactly the same with those described previously for the estimation of the CO2 emissions reduction. Considering that the market split regarding fuel type consumption is approximately 70% petrol and 30% diesel, the annual reductions in petrol and diesel consumption are 33.585 litres and 14.394 litres respectively. These benefits remain constant during the project's lifetime. The quantified travel time, emissions and fuel consumption savings are presented in Table 43.

Table 43: Benefits from a BTiS implementation in Thessaloniki.

Travel Time Savings (in vehicle-hours/year)	10.489
CO2 Emissions Savings (in tons/year)	144
Petrol Consumption Savings (in Lt/year)	33.585
Diesel Consumption Savings (in Lt/year)	14.394

The monetization of the quantified benefits is based on the determination of all the relevant cost factors for each benefit category. This task has been facilitated with the use of the cost factors provided in the HEATCO report. This report was finalized in 2006 and the estimated cost factors represent 2002 socio-economic conditions across EU. Therefore, it is essential that the cost factors are converted to present values (i.e. 2014 estimates), so that the projected benefits can be monetized. The conversion is done utilizing the present value formula (i.e. Equation 1) and the growth rate is equal to the annual growth rate of GDP per capita of the corresponding country that the deployment of the ITS is taking place. Detailed information regarding the annual growth rate of GDP per capita of each country can be found through the website of The World Bank. The annual growth rate of GDP per capita in Greece since 2002 is presented in Table 44.

Table 44: Annual Growth Rate of GDP/capita in Greece since 2002

Year	Annual Growth Rate of GDP/capita
2002	0,031
2003	0,056
2004	0,040
2005	0,019
2006	0,052
2007	0,032

2008	-0,004
2009	-0,031
2010	-0,047
2011	-0,069
2012	-0,067
2013	-0,033

The value of travel time per year in Greece since 2002 is estimated according to the relevant annual growth factor of GDP per capita and is presented in Table 45. The cost factor regarding CO2 emissions in Greece for 2014 can be directly obtained from the HEATCO report. For the estimation of the economic benefit from fuel savings current (i.e. 2014) petrol and diesel market prices are used. As it has been already mentioned, the identified benefits from a potential implementation of Romania's intermodal travel planning system in Greece are travel time, CO2 emissions and fuel consumption savings. The relevant cost factors for the latter three benefits are presented in Table 46. The values of the cost factors are considered constant throughout the project lifetime, so that benefits are not overestimated.

Table 45: Value of travel time per year in Greece since 2002

Year	Value of Travel Time (€)
2002	19,42
2003	20,51
2004	21,33
2005	21,73
2006	22,86
2007	23,59
2008	23,50
2009	22,77
2010	21,70
2011	20,20
2012	18,85
2013	18,23

Table 46: Cost factors for the Greek system

Value of Travel Time (€/hour)	18,23
Value of CO_2 Emissions (€/tonne)	26
Value of Petrol Fuel (€/litre)	1,55
Value of Diesel Fuel (€/litre)	1,23

Finally, future benefits have to be discounted to present values, so that the benefit-cost ratio can be finally estimated. Having assumed a social discount rate of 7% and using the present value formula (i.e. Equation 1) the discounted values per year are obtained. These values are shown per benefit category in Table 47, 48, and 49. The total present value of the benefits amount to 1.406.289 € and the benefit-cost ratio is 15,20.

Table 47: Travel time savings (Intermodal Travel Planning System)

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of Vehicle-hours	10488	10488	10488	10488	10488	10488	10488
Value of Travel Time (€/hour)	18.23	18.23	18.23	18.23	18.23	18.23	18.23
Travel time savings (€)	191180	191180	191180	191180	191180	191180	191180
Discounted Values (€)	178673	166984	156060	145850	136309	127391	119057
Total Benefit (€) (Present Value)							1.030.325

Table 48: Savings generated from CO2 emissions reduction (Intermodal Travel Planning System).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of CO2 emissions (tons)	144	144	144	144	144	144	144
Cost factor (€/ton)	26	26	26	26	26	26	26
Savings (€)	3.744	3.744	3.744	3.744	3.744	3.744	3.744
Discounted Values (€)	3.499	3.270	3.056	2.856	2.669	2.495	2.332
Total Benefit (€) (Present Value)							20.177

Table 49: Savings generated from fuel consumption reduction (Intermodal Travel Planning System).

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of consumed Petrol (litters)	33585	33585	33585	33585	33585	33585	33585
Price of petrol (€/litter)	1,55	1,55	1,55	1,55	1,55	1,55	1,55
Savings (€)	52057	52057	52057	52057	52057	52057	52057
Reduction of consumed Diesel (litters)	14394	14394	14394	14394	14394	14394	14394

Price of diesel (€/litter)	1,23	1,23	1,23	1,23	1,23	1,23	1,23
Savings (€)	17705	17705	17705	17705	17705	17705	17705
Total Savings from Reduction of Fuel Consumption (€)	69761	69761	69761	69761	69761	69761	69761
Discounted Values (€)	65198	60932	56946	53221	49739	46485	43444
Total Benefit (€) (Present Value)							375.964

8. CONCLUSIONS

In this present report the activities that were undertaken for the economic appraisal of the systems that were piloted within the SEE-ITS project have been described. A cost-benefit analysis regarding the ATIS demo system that has been implemented in Thessaloniki, Greece is initially presented. Subsequently, the transferability of the applications/services implemented in the other countries involved in the SEE-ITS project to the Greek road transport network is evaluated in economic terms too. The conduct of the presented CBA's heavily relies on the findings of previous research activities of the aforementioned project.

A detailed description of the development/infrastructure, operation and maintenance costs pertinent to each ITS system is provided in project activity 5.3. The assessment of the impacts of each system on traffic operations and the environment along with the transferrable impacts from foreign pilot sites to the Greek road transport network is presented in project activity 6.1. The evaluation lifecycle of each ITS is 7 years and the social discount rate for the estimation of the present values of future benefits is 7,00%. No projections are made regarding future benefits (i.e. the impacts of the first year of the system operation are deemed to remain constant), so that benefits are not eventually overestimated. The monetization of the identified impacts has been conducted according to cost factors previously estimated through the HEATCO report. The economic assessment is done in terms of a benefit-cost ratio (BCA).

An Advanced Traveller Information System has been deployed in Thessaloniki's urban road network. The system is comprised of 25 Bluetooth devices and 4 Variable Message Signs (VMS), which are operated through the city's traffic management centre. The assessment of this system's impacts showed significant travel time, fuel consumption and CO2 emissions savings. Despite its high implementation cost, the BCA of this transport project was estimated 14,19, which demonstrates the prospective benefits of this service.

The transfer of Vienna's C-ITS to Thessaloniki could possibly yield reduction in the number of occurring accidents, along with travel time, CO2 emissions and fuel consumption savings. The respective BCA is 1,79, which implies that system's implementation is desirable with respect to economic terms. Although Thessaloniki's bicycle network is currently underdeveloped and the number of cyclists is low, a prospective implementation of Budapest's travel planning service for cyclists in Thessaloniki could also generate significant benefits regarding the city's traffic operations. In this case benefits are higher than costs as well, since BCA is 3,49.

Sofia's Bluetooth information system was a small scale implementation and the transferrable impacts identified through project activity 6.1 might not yield similar results regarding an implementation along Thessaloniki's ring road. However, according to current estimates (i.e.

BCA is 0,27) such a system is not desirable from an economic viewpoint. The implementation of a dangerous goods monitoring system though along Thessaloniki's ring road could reduce the number of accidents involving slight or severe accidents along this highway corridor. The estimated benefits in monetary terms are higher than the costs and the respective BCA of this project is 1,38.

Finally, the implementation of an intermodal travel planning system to serve traffic demand on the Athens-Thessaloniki national road axis produces significantly more benefits (i.e. travel time, CO2 emissions and fuel consumptions savings) compared to the estimated costs. The BCA in this case is 15,20. Overall, it is demonstrated that ITS can provide cost efficient solutions to increase road safety, mitigate traffic congestion and ameliorate its negative environmental impacts.

9. REFERENCES

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