

INTELLIGENT TRANSPORT SYSTEMS DEPLOYMENT IN THESSALONIKI: ASSESSMENT OF COSTS AND BENEFITS

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Transportation projects often require large initial investments and are expected to generate benefits extending far into the future. Thus, there is a need to compare benefits and costs that occur at different periods over time. Since money has a time value, the same amount of money at different time periods does not have the same value. Therefore, it is important to convert costs and benefits into equivalent values when conducting a Cost-Benefit Analysis (CBA). A special category of transportation projects is that of Intelligent Transport Systems (ITS). ITS comprise innovative solutions for travel demand and traffic management, and it is expected to play a key role in future sustainable urban development plans. Compared to other transportation projects, ITS have a lower initial investment. In this paper a framework based on a CBA is presented, assessing costs and benefits of three ITS projects implemented in Thessaloniki, Greece. The paper refers to future developments of ITS in the city of Thessaloniki. The examined systems have already been developed as demonstration systems in various regions throughout Europe. The benefits of the systems have been transferred and scaled up, so as to be in line with the specific characteristics of the Greek environment.

Key words: Intelligent Transport Systems, Cost-Benefit Analysis.

INTRODUCTION

The term “Intelligent Transport Systems” or “ITS” is used to define the use of Information and Communication Technologies (ICT) in the field of transport, to create real time flow of information and data in order to enable more “intelligent” use of infrastructures and vehicles and to enhance the management of traffic and mobility (Giannopoulos *et al.*, 2013). The goal of ITS is to minimize accidents, traffic congestion, and reduce the environmental impacts of traffic, while services are affordable, privacy is respected and security is provided. In Greece, a national ITS strategy has been developed that prioritized for the first time the objectives of ITS in the country (Ministry of Economy, Infrastructure, Shipping & Tourism, 2015). These objectives pertain to the utilization of real time traffic data for the provision of relevant information to the drivers, the development of traffic control centers for the management of public transport, freight transport and monitoring of the road network, as well as the promotion of electronic transactions in transport and connectivity among vehicles

and between infrastructure and vehicles. These priorities are in compliance with the role of ITS in Thessaloniki, as this has been described in the city’s Sustainable Urban Mobility Plan (Thessaloniki Public Transport Authority, 2014). The significance of integrating innovative solutions (i.e. ITS) in the development of sustainable urban plans has been stressed by Thoidou (2013).

Previous research indicates that investments on ITS can generate quickly significant returns (Stevens, 2004). However, field data regarding actual ITS implementations that are necessary for the conduct of CBAs of ITS are normally not available. Thus, it is frequently required to estimate this information from available evidence using expert intuition (Stevens, 2004). Although there is comprehensive research literature on the estimation and monetization of environmental impacts (i.e. noise levels, climate change, etc.) of ITS systems, there is little consensus regarding the proposed valuation methods among the research community. Regarding the positive and negative effects of ITS projects, it has to be mentioned that the distribution of these effects among the various stakeholders plays a key role in the way the projects are perceived (Stevens, 2004).

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Several studies have been conducted for the economic appraisal of ITS systems utilizing different valuation methodologies. Ozbay and Bartin (2004) proposed a new evaluation methodology that integrates a full marginal cost (FMC) approach with microscopic simulation to compare the effectiveness of Advanced Traveller Information Systems (ATIS) that operate via Variable Message Sign (VMS) guidance. Their proposed methodology employed microscopic simulation as a tool for accurately estimating the impact of VMS route guidance on congestion levels that are in turn used as the input to the FMC functions. Brand *et al.* (2004) conducted a comprehensive CBA that was performed based on the results of model deployments of CVISN (Commercial Vehicle Information Systems and Networks) systems that provide electronic credentialing and electronic screening of heavy trucks to improve their safe and efficient operation.

Haynes and Li (2004) developed analytical alternatives in ITS economic evaluation that internalize positive externalities of ITS and incorporate system consideration into CBA. De Brucker *et al.* (2004) described the theoretical foundations of multicriteria analysis (i.e. analytic hierarchy process and PROMETHEE) and critically examined the strengths and weaknesses of multi-criteria analysis (MCA) as compared to cost benefit analysis (CBA), especially in the context of ITS applications. Filipovic (2007) indicated the usefulness of analytic hierarchy process (AHP) as a tool for decision making. Nakanishi and Falcochio (2004) assessed the performance of ITS using data envelopment analysis (DEA). In their work they discussed the potential of DEA to make significant contributions to the evaluation of public sector investments in ITS technologies.

In this present study a comprehensive CBA regarding the implementation of three traffic management and traveler information systems has been conducted. These ITS have been developed within the framework of the SEE-ITS project in Austria, Greece and Hungary. The cost and benefits of the implemented ATIS in Thessaloniki, Greece are estimated and compared. The prospective transfer of the ITS systems that have been developed in Austria and Hungary to Thessaloniki, Greece is also assessed in economic terms.

COST-BENEFIT ANALYSIS FRAMEWORK

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.

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:

- Time costs (Time in minutes * Value of Time in €/minute);
- User charges (e.g. fares/tolls); and
- 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 (Developing Harmonized European Approaches for Transport Costing and Project Assessment, 2002). In the abovementioned study different valuation methods of Value of Time have been used for different trip purposes.

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 (CE Delft, 2007). 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 other externalities (e.g. the environment).

Environmental Impacts of a Transport Project

Air pollution, greenhouse gases and noise costs are primary external cost categories (CE Delft, 2007). These costs comprise of health costs, building/material damages, crop losses and costs for further damages for the ecosystem (biosphere, soil, water). Previous research has evaluated the impacts of incident management on air pollution and fuel consumption along Athens Ring Tollway (Kopelias *et al.*, 2013). Investments on ITS technologies and infrastructure can possibly generate significant benefits regarding the surrounding environment (i.e. natural and man-made). The quantification of changes in pollutant emissions, greenhouse gases emissions and noise levels after an ITS project implementation is necessary for the valuation of these environmental impacts. Values regarding emission and noise cost factors for EU member countries can be obtained from the following project report "Developing Harmonized European Approaches for Transport Costing and Project Assessment" (2002).

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:

$$P = F \cdot (1+r)^N$$

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. 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 NPV 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.

RESULTS AND DISCUSSION

Mobility characteristics of the city of Thessaloniki

Thessaloniki is the second largest city in Greece, currently accommodating 1,006,730 citizens in its greater area. It is situated in Northern Greece, and covers a total of 1,455.68 km² with an average density of 665.2 inhabitants per km². Travel demand information has been obtained through 5,000 household phone surveys and Road Side Surveys (RSS) at 40 locations including 33,000 participants, executed between October and November 2010 (Mitsakis *et al.*, 2013). According to these surveys, the average number of persons in a household is estimated at 3.03 and the respective average of driving license holders per household at 1.75. Additionally, 71% of the population owns at least one private car. The average number of trips per person is 2.08. 89.4% of the survey participants stated that they usually execute up to two trips per day. Among various trip purposes, 47.6% of the trips are conducted for work and 26.8% for leisure. The modal split analysis shows that the majority of trips is conducted with private vehicles (67% private cars, 4% motorcycles and 4% taxis), while 23% is conducted with public transport (PT) and 2% with non-motorized modes of transport.

Cost-benefit analysis of ATIS in Thessaloniki

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 cost 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 VMS. Each VMS has a value of 48,000 €. 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 €.

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 investment cost has been paid out entirely in the base year of the evaluation (i.e. 2013), while the operational costs begin in 2014 (the first year of operation) and remain constant for the following years. On the other hand the maintenance costs begin 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 5.00%, the present value for each year having as a reference the year of 2013, is calculated using Equation 1. The total

NPV of the infrastructure, operation and maintenance costs is estimated to be 341,176 €. The calculated values for the system's costs are presented in Table 1.

In a cost-benefit analysis 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 CO₂ 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.

Regarding the Greek system the benefits that have been identified are travel-time, fuel consumption and CO₂ 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. For CO₂ emissions costs factors, relevant values are provided for the year 2014 in HEATCO,

Table 1. 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	2,624	2,624	5,286	5,286	5,286	5,286	5,286
Total Cost (€) (Present Value)								341,176

Table 2. Benefits from the implementation of an ATIS in Thessaloniki

Year	2014	2015	2016	2017	2018	2019	2020
Reduction of Vehicle-hours	27,041	27,041	27,041	27,041	27,041	27,041	27,041
Value of Travel Time (€/hour)	18.23	18.23	18.23	18.23	18.23	18.23	18.23
Travel time savings (€)	492,912	492,912	492,912	492,912	492,912	492,912	492,912
Discounted Values (€)	469,440	447,086	425,796	405,520	386,209	367,818	350,303
Reduction of CO2 emissions (tons)	254	254	254	254	254	254	254
Cost factor (€/ton)	26	26	26	26	26	26	26
Savings (€)	6,607	6,607	6,607	6,607	6,607	6,607	6,607
Discounted Values (€)	6,292	5,992	5,707	5,435	5,176	4,930	4,695
Reduction of consumed Petrol (litters)	67,872	67,872	67,872	67,872	67,872	67,872	67,872
Price of petrol (€/litter)	1.55	1.55	1.55	1.55	1.55	1.55	1.55
Savings (€)	105,202	105,202	105,202	105,202	105,202	105,202	105,202
Reduction of consumed Diesel (litters)	16,968	16,968	16,968	16,968	16,968	16,968	16,968
Price of diesel (€/litter)	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Savings (€)	20,871	20,871	20,871	20,871	20,871	20,871	20,871
Total Savings from Reduction of Fuel Consumption (€)	126,072	126,072	126,072	126,072	126,072	126,072	126,072
Discounted Values (€)	120,069	114,351	108,906	103,720	98,781	94,077	89,597
Total Cost (€)(Present Value)							3,619,902

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. The benefits that arise from the implementation of the project are provided in Table 2.

Cost-benefit analysis of a cooperative traffic management system in Thessaloniki

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 5.00% and using the present value formula the discounted values per year are obtained. These values along with the initial development cost are shown in Table 3.

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. 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. The total present value of the benefits amount to 118,533 € and the benefit-cost ratio is 1.92. The benefits

that arise from the implementation of the system are provided in Table 4.

Cost-benefit analysis of ITS deployment for road networks in Thessaloniki

The development cost corresponds to the building of an 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 Hungary and Greece during the base year of the project evaluation lifecycle. The ratio of the Greek GDP per capita (PPP) to Hungary's GDP per capita (PPP) is estimated and this index is multiplied by the development cost in Hungary. 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 1,320 €. 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 5.00 % 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 5.

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. 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 total present value of the benefits amount to 171,999 € and the benefit-cost ratio is 3.69. The benefits that arise from the implementation of the system are provided in Table 6.

CONCLUSIONS

In this present study the activities that were undertaken for the economic appraisal of three systems that were

Table 3. 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	274	261	249	237	226	215	205
Total Cost (€) (Present Value)								61,666

Table 4. Benefits from the implementation of a C-ITS in Thessaloniki

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 (€)	11,736	0	10,645	0	0	9,195	8,758	
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 (€)	15,018	0	13,622	0	0	11,767	11,207	
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 (€)	393	0	357	0	0	308	293	
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 (€)	7,342	0	6,660	0	0	5,753	5,479	
Total Cost (€) (Present Value)								118,533

Table 5. 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	1,505	1,505	1,505	1,505	1,505	1,505	1,505
Total (€)	37,848	1,505	1,505	1,505	1,505	1,505	1,505	1,505
Discounted Total (€)	37,848	1,433	1,365	1,300	1,238	1,179	1,123	1,069
Total Cost (€) (Present Value)								46,555

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 Austria and Hungary 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 the research activities of the SEE-ITS project.

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 10.76, 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 1.92, 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 3.69.

Overall, it is demonstrated that ITS can provide cost efficient solutions to increase road safety, mitigate traffic congestion and ameliorate its negative environmental impacts. A future coordination of the operation of the three individual services is proposed, that could potentially bolster their current positive traffic and environmental effects. A CBA of the prospective coordinated system would be valuable for the assessment of the enhanced effects of the new system in monetary terms, and for the conduct of a comparison with the results presented in this study.

Table 6. Benefits from the implementation of a route planning system in Thessaloniki

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 (€)	17,257	16,435	15,652	14,907	14,197	13,521	12,877
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 (€)	562	535	510	485	462	440	419
Reduction of consumed Petrol (litters)	5,303	5,303	5,303	5,303	5,303	5,303	5,303
Price of petrol (€/litter)	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 (litters)	2,273	2,273	2,273	2,273	2,273	2,273	2,273
Price of diesel (€/litter)	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 (€)	10,491	9,991	9,516	9,062	8,631	8,220	7,829
Total Cost (€) (Present Value)							171,999

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