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QUANTIFYING THE BENEFITS FROM A MAJOR INFRASTRUCTURE IMPROVEMENT: THE CASE OF THESSALONIKI WESTERN RING ROAD UPGRADE TO ELIMINATE AT GRADE SIGNALISED INTERSECTIONS

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Abstract

Thessaloniki is the second largest city in Greece and its transportation system (development and operation) is hampered by the city's geographical position and surrounding relief. Specifically, the city has been developed and expanded through the years along the coastline, the sea boundary on the southwest, and a second physical boundary, a forest, on the east side. The Thessaloniki Ring Road (divided in western and eastern part) was constructed in the early '90s, in order to relief the road network of the city centre from the transit traffic and confront the gradually increasing congestion. The absence of alternatives other than road transport and the increase of car ownership over the years led to an increase of motorized traffic. So even that this Ring Road had been designed to serve 30,000 vehicles daily it became to serve more than triple traffic just before the impacts of the economic crisis on transport and mobility have been made visible.

The Western Internal Ring Road of Thessaloniki (**WIRRT**) has length of 8.4km. It has three lanes per direction separated by a median and no emergency lanes. The traffic increase and moreover the existence of eight at grade intersections along the WIRRT degrade the provided level of service. For the elimination of these intersections an upgrade project is underway for implementation that includes the construction of five grade separated intersections and several interventions on the adjacent road network. This paper presents in brief the methodology and the results of the project's Cost-Benefit Analysis, which assessed the expected socioeconomic benefits, emerging mainly from minimising the delays for users due to the elimination of the at grade signalised intersections.

Keywords: Thessaloniki Ring Road, Signalised intersection, Grade separated intersection, Cost – Benefit Analysis.

1. INTRODUCTION – PROJECT DESCRIPTION

In the current situation the WIRRT – as it is nowadays called, because in the meantime the External Ring Road of the city was constructed as part of the Egnatia Motorway, see **Figure 1** – has six lanes in total (three per direction), without emergency lanes and with a median for separation of the opposite circulating traffic. Despite its relatively wide cross-section the WIRRT does not provide the maximum of the expected Level of Service (**LoS**), which is degraded by the existence of substantial number of at grade intersections along its length, and where traffic signalization is in operation for the traffic management, i.e. for the service of the vehicles crossing vertically the WIRRT or entering/ exiting the WIRRT.

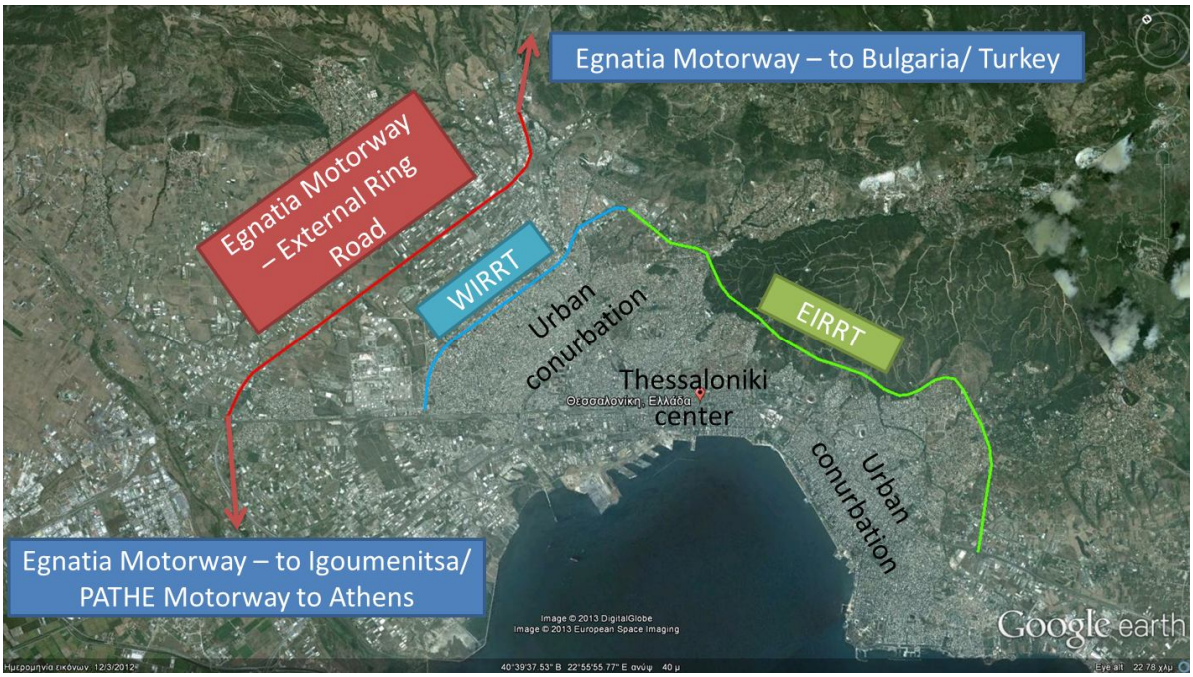

Figure 1. Map of Western and Eastern Ring Road in relation to the city and Egnatia Motorway (the only constructed part of the External Ring Road)

The project concerns the improvement – upgrade of the existing infrastructure of the WIRRT for a length of approximately 6km. It mainly includes the elimination of all the at grade intersections through the construction of five grade separated intersections (**I/C**). Furthermore several interventions are foreseen on the local and service roads for traffic management and channelization and for the improvement of the WIRRT accessibility. The project

targets to the direct increase of the capacity/ LoS and at the same time to strengthen the road safety level for all the categories of infrastructure users (drivers and pedestrians). Specifically, the main construction works concern:

a) construction of the grade separated I/C 3rd Septemvriou, with construction of two overpasses of Vembo and 3rd Septemvriou, combined with upgrades of the connection roads;

b) construction of the grade separated I/C Meandrou, with underground passing of the WIRRT, combined with construction of connecting roads of Meandrou street and formulation of a round-about over the WIRRT (i.e. elimination of the existing signalized intersection at the same level);

c) construction of the grade separated I/C Makriyianni, with underground passing of the WIRRT, combined with construction of connecting roads of Makriyianni street formulation of two round-about over the WIRRT and a connecting road between them over the WIRRT (i.e. elimination of the existing signalized intersection at the same level);

d) construction of the grade separated I/C Langadha – Stavroupoleos, through the construction of two separated bridges over the Langhada and Oreokastrou streets;

e) construction of the grade separated I/C K14 (25th Martiou/ Stratou) – Efkarpias, with underground passing of the WIRRT, combined with construction of connecting roads of 25th Martiou street and formulation of a round-about over the WIRRT (i.e. elimination of the existing signalized intersection at the same level).

Additionally are foreseen the substitution of guardrails, central median and asphalt layers for the entire length of the WIRRT, construction of Traffic Management and Electro-Mechanical buildings and interventions on rest of the service and local road network.

2. METHODOLOGY – PARAMETERS OF THE ANALYSIS

2.1. Investment cost – Cost allocation – Analysis period

The total investment (financial) cost of the project according to the preparatory studies has been estimated at 155.45mo€, VAT included. This cost includes, apart from the construction costs, the costs of necessary studies, consultancies, restoration of the networks of Public Organisations Utilities, archaeological works, additional expropriation costs, prices revisions and contingencies. The foreseen annual allocation of expenditures is 0.58%

(0.9mo€) in 2012, 41.12% (63.9mo€) in 2013, 43.17% (67.1mo€) in 2014 and 15.13% (23.53mo€) in 2015.

The economic cost used in the socioeconomic analysis is 91.7mo€, which represents 76.1% of the investment cost without VAT.

The project is under preparation (start of expenditures) since the year 2011 and it is foreseen to be implemented in the period 2013 – 2015. As for the analysis period, the designated period for transport infrastructure projects is 25 to 30 years, but only when reliable demand forecasts exist up to this time horizon. It was deemed insecure to extend the 25 years period even for five years, since even the forecast for 25 years horizon under the prevailing socioeconomic conditions is considered risky. Therefore, the period of analysis is set to be 25 years from the planned conclusion of the project and its opening to traffic, i.e. 28 years in total including construction period.

2.2. Traffic analysis and estimation of the future transport demand

Traffic analysis is of fundamental importance for the Cost Benefit Analysis, due to the fact that any of the project benefits are quantified and are input to the analysis, are directly associated with the existing and future demand and therefore with the operation of WIRRT in both the scenarios of preserving the existing infrastructure or implementing the upgrade project under study.

The available actual traffic data were for the years before the crisis and therefore for the analysis processed traffic data from the traffic simulation model developed and managed by the Hellenic Institute of Transport (H.I.T.) of the Greek Centre for Research and Technology (CE.R.T.H.) have been used.

Based on this data processing, the Annual Average Daily Traffic (expressed in Passenger Cars Units – **PCUs**) at the intersections of WIRRT in 2012, base year of traffic forecast, were: 32,500PCUs/day at each of the signalized intersections of WIRRT with Mbotsari and Ath. Diakou streets (30,000 in both directions on WIRRT), 44,789PCUs/day at the signalized intersection of WIRRT with Meandrou street (31,380 in both directions of WIRRT), 54,228PCUs/day at the signalized intersection of WIRRT with Makriyianni street (37,236 in both directions of WIRRT), 51,638PCUs/day at the signalized intersection of WIRRT with Oreokastrou street (41,033 37,236 in both directions of WIRRT), 59,148 PCUs/day at the signalized intersection of WIRRT with Langadha street (44,793 in both directions of WIRRT) and 51,697 PCUs/day at the signalized intersection of WIRRT at Efkarpia (43,990 in both directions of WIRRT). A separate analysis for each one of the signalized

intersections resulted that the examined WIRRT intersections serve (cumulative for all circulating vehicles at all intersections) approximately 100 million PCUs annually.

The intersections examined operate as “cross type” and “T type” intersections. The movements of the vehicles and of the pedestrians are controlled by traffic lights with average cycle (time period) of 95 seconds. Obviously the times of green light endure more for the movements of the vehicles moving along the WIRRT, than for the vehicles moving on the vertically accessing roads, and varies based on the geometry and physical design of each intersection.

For the analysis of the traffic flows, the “British” method was applied due to the fact that the available traffic flows were calculated per hour and for each one of the roads of the intersections. Moreover the “British” method could simulate the operation of the intersections in a more realistic way than the alternatives methods and especially the U.S. method.

According to the analysis, the LoS of the intersections are C (intersections Mbotsari and Oreokastrou), D (intersections Meandrou, Makriyianni, Langadha and Efkarpias) and E (Ath. Diakou intersection). Another important finding from the examination of the daily fluctuation of traffic is that the delays at the various intersections along the WIRRT are repeated also beyond the traditional peak hours (morning, midday, afternoon). Specifically traffic volumes similar to peak hour volumes appear from five to nine times during the day, which is an evident of the widening of the peak hours of the day where congestion is observed.

Regarding the traffic demand forecast, in absence of a transport planning model and network approach, it was considered that traffic demand follows the evolution of GDP. Therefore, based on the latest (and theoretically valid) GDP forecasts from international organisations/ institutions (International Monetary Fund, European Union), growth factors have been used, appropriately adjusted. According to relevant studies of Egnatia Odos S.A. it was considered that the annual change in transport demand follows the respective annual change in GDP at a percentage of 80%.

Concerning the GDP evolution, it was considered that, according to IMF forecasts, the GDP will follow an increasing trend from year 2013 and after, with a growth factor of about 2.2% until year 2020. Then a gradual decrease is assumed, with annual increase above 1% up to year 2030 and then, during the last decade of the analysis the evolution of GDP follows a declining pattern, with annual growth factors that are reduced up to 0.8% at the end of the analysis

period (2040). Based on the aforementioned assumptions, it is estimated that the annual served vehicles (expressed in PCUs) at the various intersections along the WIRRT will be increased by 43% by the year 2040.

It should be additionally noted that, in order to avoid overestimations of the project economic indices, no diverted nor induced or generated traffic have been accounted in the analysis, since their estimation is subjected to limitations of available data. It is expected that the benefits from the project implementation would be higher, if it would be possible to calculate the shifted traffic from the city road network as well as from the External Thessaloniki Ring Road after the introduction of infrastructure charging system, which is underway.

Based on the annual projections of traffic, LoS have been calculated for each year for the life time period of the project (time period 2013 – 2040) for all intersections in case of not implementing the project. The LoS of the intersections in the future will be reduced, not necessarily in terms of changing level of service due to the moderate demand forecast, but mainly in terms of delays. Nowadays delays during the peak hours are on average 3.4 minutes for the users of the entire length of the 6km of the WIRRT (where the signalised intersections are).

2.3. Economic Construction, Operation and Maintenance Costs

The economic cost of the investment has been calculated as percentage of the total cost, which after deduction of the VAT and the contingencies was considered at 76.1% of this cost (aggregated percentage of 62.5% in comparison with the total financial investment). In the calculation of the economic indices of the project, this percentage has been applied on the financial cost, excluding contingencies, since the surcharge with such expenditures is examined at later stage, in the sensitivity analysis, as a scenario of investment costs increase. Thus, the economic cost of the investment is estimated at 91.71mo€, whilst in terms of present value at 79.3mo€.

Concerning the maintenance and operation costs, they were calculated as percentage of the project cost, for both the annual and the periodical maintenance. The cost of annual maintenance and operational (**O&M**) cost is assumed at 2% of the project cost (0.456mo€/year), while the periodical (every 10 years) heavy maintenance cost at 3% of the total project cost (3.65mo€). The total O&M costs in terms of present values are estimated at 21.2mo€.

2.4. Project quantifiable benefits

The benefits from the project implementation are expected from: a) the reduction of running times for the users of the WIRRT, as well as for the users of the existing signalized intersections that will be eliminated, b) the reduction of vehicles operational costs due to the high reduction of the delays observed in the existing situation and is foreseen to be intensified in the future in case that the project would not be realized and c) due to the reduction of road accidents.

In order to quantify these benefits several estimations and assumptions had to be made, which were based on previous data, updated and customised so that they reflect the current economic situation in Greece.

The operational cost of the vehicles would be less in the future due to the fact that the vehicles will not be obligated to decelerate and accelerate at each intersection as presently. For this benefit only fuel savings have been considered in the analysis due to insufficient data to estimate how many users use each intersection, in order to avoid overestimations. The fuel cost used was 0.64€/lt for petrol and 0.81€/lt for diesel and the fuel consumption during a vehicle is stationary was considered 0.5lt/h. No increase of fuel costs was considered during the analysis period, again to avoid overestimations.

Since the main benefits are associated with the time savings for the users, a very detailed approach was followed to estimate the time lost at signalised intersections, which will be the gain for the users after the project realisation. Therefore, the assumptions made were that the length of the intersection is 50m, the braking time for vehicles running with 90km/h (speed limit of WIRRT at present) is 3.8seconds, the evacuation time of the last vehicle passing the intersection is 4.5seconds (speed of 11m/sec) and the acceleration time for the first vehicle passing the intersection is 7.14seconds (speed of 7m/sec).

Concerning the assumptions made for the estimation of the delays and the LoS two of the basic assumptions were that the composition of the traffic will remain the same in the future and that the percentage of the turning movements will not change. A third important assumption was the preservation of traffic daily distribution as it is.

Assumptions were also made for the calculation of the annual time savings based on the hourly and daily values. Specifically, the delays were calculated on annual base based on the hourly and daily values multiplied by a factor which was adjusted to Greek reality (number of working days, summer vacations and religious holidays, etc.).

Regarding the value of time (**VoT**), it has been calculated separately for each passenger trip purpose (business, leisure, from/to work, long/short distance) and the mean value (weighted average of VoT and percentage of trips per purpose) was 14.3€/h. The car occupancy was considered 1.2 passengers. For freight vehicles a mean weight of truck of 10tonnes was assumed and the VoT per tonne was considered to be 3€/h.

For the users crossing the entire WIRRT it was considered that they will benefit 100% from the elimination of the at grade intersections, while for the users crossing the WIRRT vertically that they will benefit from the roundabout establishment by 80% of the time spend at the signalised intersection.

For road safety and the expected reduction of road accidents, previous data were analysed and assumptions were made. The monetary value of human life and the value of the injuries adopted were based on the international literature (update of values from HEACTO study) but they had to be customised based on the financial crisis in Greece and the labour cost which is significantly reduced. The cost of human life considered is 1.183mo€, of severe injury 0.155mo€ and of light injury 0.012mo€. The reduction of accidents was considered that would be by 60%, since the main cause of accidents was the violation of traffic signals, according to data from the Greek Police Authorities.

In **Table 2** are presented the estimation of the quantified benefits of the project in terms of Net Present Value, including the project's residual value:

Table 2. Contribution of benefits to the economic indicators

Benefits (savings due to)	Net Present Value (mo€)	Percentage
Running times reduction	136.65	82.1%
Reduction of Vehicles Operational Costs	3.60	2.2%
Accidents reduction	15.70	9.4%
Residual value	10.50	6.3%

3. RESULTS OF THE SOCIOECONOMIC ANALYSIS

The interest rate use is 5.5%, based on the relevant guidelines of EC. According to the assumptions described in the previous paragraphs, the Economic Internal Rate of Return (EIRR) of the project is estimated at 10.87%, its Economic Net Present Value (ENPV) at 64.9mo€ and the Benefits/ Costs Ratio (B/C) at 1.66.

Additional tests for interest rate alterations resulted that using an interest rate of 5% increases the ENPV by 10.5mo€ and the B/C ratio to 1.74, whilst using interest rate of 6% reduces the ENPV by 9.5mo€ and the B/C ratio to 1.58.

Table 3. Calculation of Net Cash Flow and economic indicators

Year	Accidents reduction (mo€)	Time savings (mo€)	VOC reduction (mo€)	Total revenues (mo€)	Operating costs (mo€)	Investment costs (mo€)	Total expenditures (mo€)	Net cash flow (mo€)
2012	0.000	0.000	0.000	0.000	0.000	0.532	0.532	-0.532
2013	0.000	0.000	0.000	0.000	0.000	37.711	37.711	-37.711
2014	0.000	0.000	0.000	0.000	0.000	39.590	39.590	-39.590
2015	0.000	0.000	0.000	0.000	0.000	13.879	13.879	-13.879
2016	1.248	10.360	0.241	11.849	1.834	0.000	1.834	10.015
2017	1.274	10.701	0.250	12.225	1.834	0.000	1.834	10.391
2018	1.301	10.932	0.256	12.490	1.834	0.000	1.834	10.655
2019	1.327	11.218	0.265	12.810	1.834	0.000	1.834	10.976
2020	1.351	11.415	0.271	13.037	1.834	0.000	1.834	11.202
2021	1.374	11.747	0.280	13.401	1.834	0.000	1.834	11.567
2022	1.397	11.944	0.284	13.625	1.834	0.000	1.834	11.791
2023	1.419	12.196	0.287	13.902	1.834	0.000	1.834	12.068
2024	1.441	12.524	0.309	14.274	1.834	0.000	1.834	12.440
2025	1.462	12.752	0.319	14.532	1.834	0.000	1.834	12.698
2026	1.481	12.993	0.330	14.805	3.668	0.000	3.668	11.137
2027	1.500	13.160	0.341	15.002	1.834	0.000	1.834	13.167
2028	1.518	13.397	0.355	15.270	1.834	0.000	1.834	13.436
2029	1.536	13.552	0.367	15.454	1.834	0.000	1.834	13.620
2030	1.553	13.607	0.378	15.538	1.834	0.000	1.834	13.704
2031	1.569	13.992	0.398	15.960	1.834	0.000	1.834	14.126
2032	1.584	14.200	0.412	16.196	1.834	0.000	1.834	14.361
2033	1.599	14.414	0.455	16.468	1.834	0.000	1.834	14.633
2034	1.613	14.541	0.458	16.611	1.834	0.000	1.834	14.777
2035	1.627	14.663	0.459	16.748	1.834	0.000	1.834	14.914
2036	1.640	14.780	0.460	16.880	1.834	0.000	1.834	15.046
2037	1.651	14.887	0.461	16.999	3.668	0.000	3.668	13.331
2038	1.664	15.087	0.464	17.215	1.834	0.000	1.834	15.381
2039	1.676	15.429	0.472	17.577	1.834	0.000	1.834	15.743
2040	1.687	15.522	0.472	17.682	1.834	-44.491	-42.657	60.338

4. RESULTS OF THE SENSITIVITY AND RISK ANALYSIS

4.1. Sensitivity tests – Critical variables and switching values

For the sensitivity analysis of the results of the socioeconomic analysis several scenarios were investigated for alterations of the various parameters used, and specifically alterations of a) implementation cost, b) maintenance (both annual and periodical) and operational costs and c) parameters used for the

estimation of the project benefits (annual GDP growth, traffic forecast, values of time, fuel costs). The results of the sensitivity tests are schematically presented in **Figure 2**.

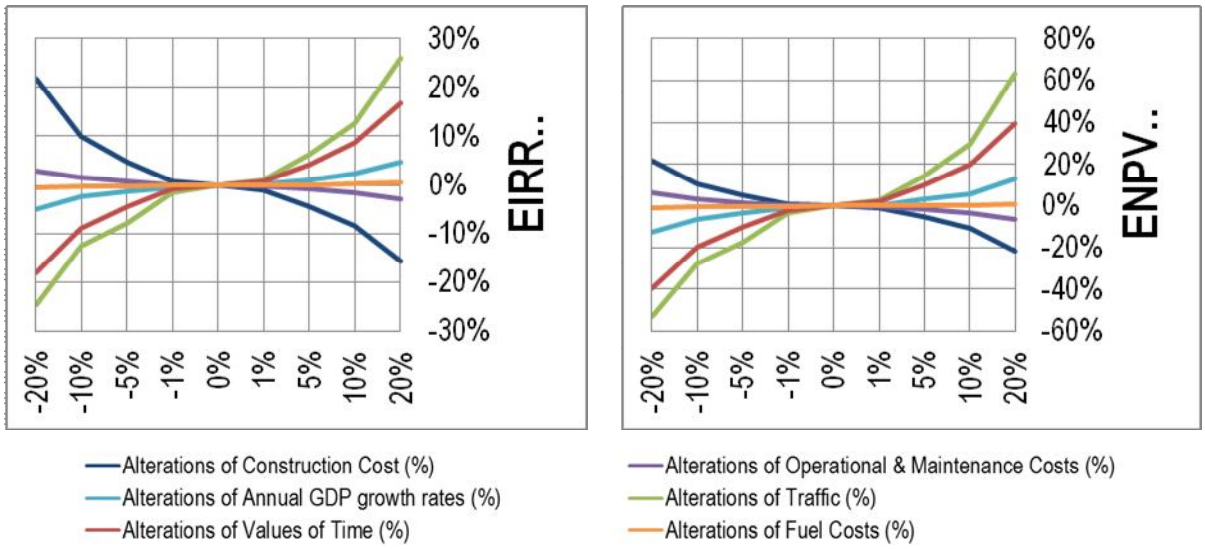

Figure 2. Results of the Sensitivity Analysis

Based on the sensitivity tests, the parameters which can be considered as critical are the demand, the values of time used and the implementation cost. Demand is a critical parameter due to the fact that the project benefits are quantified in relation to the forecasted traffic values and a reduction of demand by 5% leads to EIRR of 10%, by 10% to EIRR of 9.5% and by 20% to EIRR of 8.2%. Regarding values of time, they are critical because the biggest share of the project benefits are derived from the reduction of the delays and the running times for the users of the WIRRT road corridor and of the vertical roads to this road corridor. A reduction of the base time values by 5% leads to EIRR of 10.5%, by 10% to EIRR of 9.9% and by 20% to EIRR of 8.9%.

After examination of the diagrams describing the relation of the EIRR with the various alterations of the examined variables and the trends towards higher alterations, it emerges that the EIRR is reduced at the level of the interest rate used, and therefore the ENPV is marginally positive, when the reduction of the base values of time is higher than 50% or when the reduction of demand is higher than 40%. Concerning the scenarios of increase of the implementation cost, it is calculated that the ENPV is zero in the case of duplication of this cost (increase by 92%).

4.2. Risk Analysis

All the scenarios examined independently (not combined) lead to the worst case to a reduction of the ENPV by 53.08% and of the EIRR by 24.53%, and this concerns the scenario of reduction of the VoT of the road users by 20%. However, even in this case the project has positive socioeconomic indices.

Furthermore, several other scenarios of simultaneous appearance of the worst alterations of the parameters examined independently in the sensitivity analysis (reductions by 20%) were made.

The scenario of simultaneous increase of the implementation cost by 20% and reduction of the demand by 20% lead to EIRR of 6,76% and to ENPV of 16.5mo€. The same, extreme scenario, but with simultaneous increase of O&M costs increase by 20% lead to EIRR of 6.44% and to ENPV of 12.3mo€.

The scenario of simultaneous increase of the implementation cost by 20% and reduction of the values of time by 20% lead to EIRR of 7.39% and to ENPV of 25.34mo€. The same scenario, but with simultaneous increase of O&M costs increase by 20% lead to EIRR of 7.09% and to ENPV of 21.11mo€.

The aforementioned scenarios are considered extreme, especially concerning the scenario of reduction of demand, since in the forecast is rather moderate. It should be noted that the demand used in the analysis does not incorporate induced or diverted traffic, and therefore the calculated benefits concerning the time savings and vehicles operational costs savings could be considered underestimated.

5. CONCLUSIONS

The project is considered, since this is proved in quantitative terms, useful and beneficial for the society and the economy. Additionally, there are other substantial benefits which could not be quantified in the Cost-Benefit Analysis, like the positive effects on employment during construction and operation of the project, the improvement of the quality of life of the residents of the directly affected Municipalities of the Thessaloniki conurbation (P. Mela and Kordelio - Evosmos), as well as of all the residents of the Thessaloniki Metropolitan Area, from the increase of the attractiveness of the WIRRT against the road network through the city centre, the reduction of emissions and pollutants and the reduction of noise at all the network, the increase of the accessibility to areas of cultural and touristic interest inside and outside of the city, the improvement with the connection with the international airport of the city etc.

Based on the several sensitivity and risk tests performed, it is considered that the project is useful from socioeconomic point of view, independently from the realization of various phenomena that affect its parameters and the calculated performance indices.

However, for the prevention of these risks it is required to ensure a) during the project implementation an efficient project management and supervision system (for the monitoring of the progress of works in accordance with the time schedule, budget and spending forecast) and b) during operation period the provision of high level of service for the users of the upgraded infrastructure, in order to preserve and increase the demand, and thus to maximize the benefits for the society.

For the project management and supervision Egnatia Odos S.A., state owned company responsible for the project, has multiannual and specialized relevant experience, which concerns more complex projects than the specific project, gained from the construction of the entire Egnatia Motorway and its vertical axes, a Trans-European Transport Priority Project. Given this fact, it is considered that Egnatia Odos S.A. can ensure the timely conclusion of the project, with advanced financial management and quality assurance during construction.

Finally, for the preservation of the highest possible level of service on the upgraded infrastructure, the strict implementation of the maintenance programs and the establishment of a traffic management centre with appropriate staff and operations, could contribute in this direction.

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