Cost benefit analysis of the Athens metro line 3 expansion project

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Abstract. Metro projects have become an essential infrastructure of modern large metropolitan areas worldwide, as they provide fast, reliable and efficient transportation services, promoting overall mobility, environmental stewardship and economic vitality. In order to assist the decision-making process of pursuing such high cost underground infrastructure, its assessment should not only be based in a purely financial evaluation. On the contrary, the implementation of a comprehensive social cost-benefit analysis incorporating the monetary values of the environmental and social benefits of underground transit systems is an important element to highlight latent qualities. The paper presents an ex-post cost benefit analysis focusing on the last segment of the Athens metro line 3 expansion, from Egaleo to Ag. Marina station. This section has been developed from 2007 and was put in service in 2014. The analysis incorporates actual cost figures from the construction period as well as the operational cost of the segment during the first years of operation. The project is assessed on the grounds of an investment plan using the social NPV and social IRR criteria. The results point out that the project is not feasible if benchmarked against purely financial criteria. Nevertheless, the introduction of the monetary values attained by the social and environmental benefits that the project brings, renders the whole development desirable and beneficial from a cost-benefit analysis standpoint.

1. Introduction

Underground mass transit infrastructure or better known as metro systems have been an essential part of the cities infrastructure offering swift passage bypassing surface traffic congestion. Metros offer multiple units of high-capacity carriages that contribute to meeting current mass transit demand, while at the same time providing their passengers with greater mobility and flexibility. In 2017, there were 178 metro systems in operation accounting for a total annual ridership of almost 54 billion passengers, more than 7 times the world population, while in the last six years annual metro ridership grew globally by 19.5%. The Tokyo metro, which is the busiest in the world, carries close to 3.6 billion passengers per year. Chinese metro systems, namely the Beijing and Shanghai networks occupy the 2nd and 3rd place with a daily ridership of 3.4 and 2.8 billion passengers respectively [1]. The above clearly indicate that metros are essential infrastructure; they are – and they will continue to be – in the forefront of urban development facilitating city living and upgrading the environmental conditions of modern cities. Nevertheless, underground infrastructure of this type is usually associated with high development costs. Flyvbjerg et al. [2], [3] have found that tunnel mega projects involving large capital investments have often been justified around the world based on the exaggeration of benefits and underestimation of costs. Therefore, the question rising is firstly what can be the cost of development and secondly whether the
underground development and metro line expansion can be justified in terms of cost. The first can be answered by performing an ex-post evaluation that should assess and benchmark the accuracy of the ex-ante appraisal based on real facts. The second and most difficult one is often addressed by using both monetary and social benefits that can mutually coexist and provide insights regarding the return on the profits (or losses) under a holistic approach. This is usually made with the help of cost-benefit assessment that tries to incorporate all associated benefits to monetary values and thus to provide a common reference scale for the stakeholders to compare.

The paper is presenting an ex-post cost benefit analysis focusing on the last segment of the Athens metro line 3 expansion, from Egaleo to Ag. Marina station. This section has been developed as a separate project, has started its development in 2007 and was finally commissioned in 2014. The analysis is actually taking into account data coming from the construction as well as from the first years of operation, so as to more accurately assess the performance of the project. Through these data the calculation of capital and operational costs is accurately depicted, while, at the same time, the benefits coming from the operation of the metro line can be estimated with greater ease. Additionally, issues relating to the benefits gained through the operation of the infrastructure could be updated and depict today’s values or views relating to time losses due to traffic, air pollution as well as other benefits to the general public as derived by the use of metros. Thus, this CBA assessment can more clearly depict the importance of the metro expansion and can identify lessons learned that can be used to facilitate decisions in relevant cases.

2. Cost-Benefit Analysis (CBA) of Development Projects

Large-scale transport infrastructure projects and megaprojects are typical public projects that are financed from a country’s public investment program. Owing to the fact that public funds are limited, the relevant decision-making process focuses on calculating and determining the economic efficiency of these projects more accurately. In general, there has been a growing tendency for policy makers to use a formal methodology for selecting a project or policy among a list of alternatives. Government or private sector initiatives create social costs as well as benefits. As a result, it should be tested through a mechanism, which policies, on balance, make society ‘better off’ in some meaningful sense and help select the option or mix of options that will provide the largest social improvement [4].

Cost benefit analysis (CBA) is one of the tools used in decision-making policies, where all costs and benefits of a number of proposed alternative projects can be assessed and compared. Actually, it is the most widely used project evaluation method by both public and private sectors for comparison of various projects according to their costs and benefits. The present values of a project’s costs as well as benefits gained are calculated. This can help to identify the most promising ones, if a number of projects is compared, while in the case of evaluating a single project, the project is concluded as promising and attractive in the case where the net benefits exceed the net costs [5].

The purpose of using CBA is different for public and private sectors. While the private sector uses the method only for-profit maximization, the public sector uses it to maximize social benefit. The aim of public sector for using CBA can also be stated as to allocate resources efficiently among the projects to raise the social welfare. Given that the purpose is to maximize social welfare, the standard of CBA is the Potential Pareto Condition or in other words Kaldor-Hicks Rule, which has its roots from Pareto Optimality theorem of welfare economics [6].

Today CBA is a prerequisite in EU for the funding of many projects. The main principle of the social cost benefit analysis (SCBA) is to express the social costs as well as social benefits of policies in monetary terms so that the consequences that might arise of a variety of policies can be compared using a common metric [7]. SCBA starts with accumulation of social costs and social benefits. After determining direct and indirect costs and benefits of the examined policy it continues with their valuation technique. Stated Preference, Revealed Preference and the Life Satisfaction Approach constitute the valuation methods [8], [9], [10]. The process of SCBA continues in terms of discounting the future values of benefits. In the final stage, both costs and benefits are used to set up a cash flow table and the implementation of the Social Net Present Value (SNPV) and the Social Internal Rate of Return (SIRR)
criteria provide judgment on the feasibility of the examined plan. Hence, SCBA is actually weighting the pros and cons of a project in a rational and systematic manner [11] and assist in the decision making ensuring that the net aggregate benefits to society outweigh the net aggregate costs [12]. This is usually depicted with the help of the Benefit to Cost ratio (BCR) in which values greater than 1 represent projects that offer more benefits than costs, and with the use of economic net present value (ENPV) and economic rate of return (ERR), which incorporate the monetary effect of all benefits and costs within the project timeline.

3. Case Study – Line 3 of the Athens Metro “Egaleo-Aghia Marina”

Aghia Marina Station is an Athens metro station on Line 3, acting also as a terminal station. The station is underground and has two side docks. Near the station a transfer station with a parking capacity of 383 spaces was built. The underground parking lot was put into operation on April 14, 2014. The station's construction began in January 2007 and was completed in February 2012, but could not be delivered to the passenger public due to the pending installation of the train signaling system. The station finally became operational on December 14, 2013.

4. Ex-post analysis cost – benefit analysis

In order to implement the cost-benefit analysis we used a two-stage approach. The first stage assesses the feasibility of the project. Using the actual cost-data from the construction phase and first years of operation plus assumptions of the Attiko Metro S.A., regarding the future operational period, the project was evaluated using the Net Present Value (NPV) and the Internal Rate of Return (IRR) financial criteria. The second stage introduced the social and environmental benefits of the project, expressed in monetary terms and estimated the social NPV and IRR indices.
4.1. Financial analysis
According to the data provided by ATTIKO METRO S.A. for the project “Extension of Line 3, Section Egaleo - Chaidari, Chaidari Transmission Station, Eleonas Railway Station” and the data given from STASY S.A. the most important points and assumptions to consider for the financial analysis were:

- Construction on the project began in 2006 and was completed at the end of 2013, but it was operational in 2014. Therefore, the analysis extends from 2006 to 2043 in order to include 30 years of full project operation.
- The main source of revenues are ticket fares.
- The expenses consist of personnel wages, maintenance costs and electricity costs.
- The analysis uses the actual data (ridership, operational cost etc.) up to 2018. From then on it is assumed that the figures increase at a rate of 1.5% annually.
- The taxation is set at 29%, while a depreciation rate of 10% is assumed.
- The analysis is conducted in constant prices (2018 Euro price level). Current prices are converted to constant prices based on published data from the Hellenic Statistical Authority.
- The discount rate is equal to 4%, according to the European Union Project Evaluation Guide [13].
- The residual value of the investment was € 43,921,745 (2018 prices) and was counted as a positive cash injection, in the cashflow table, in the last year of the analysis (2043).

The results of the financial analysis prove that the Net Present Value (FNPV) is negative while the Internal Rate of Return (FIRR) is lower than the discount rate (4%), so the project is not considered financially viable.

| Financial Indicators | Value        |
|----------------------|--------------|
| FNPV                 | -71,150,663 €|
| FIRR                 | -1%          |

4.2. Economic Analysis
In order to calculate the socio-economic impact of the extension, it is necessary to compare the costs with the benefits of the construction of the project, in order to identify the socio-economic importance of the investment. In the case examined in the present paper the most important social and environmental benefits were the following:

- Travel time savings
- Vehicle Operating Cost savings
- Accident Cost savings
- Air pollution reduction
- Noise pollution reduction

The next step of the process involved the economic evaluation of the benefits from the creation of the extension of Line 3 Egaleo - Aghia Marina, with an extensive review of the environmental economy literature from selected studies, in order to estimate the selected values in the present paper. The main aim here is to establish a very good approximation of the relevant savings in monetary terms. In order to do so, the review examined similar case studies involving metro projects in countries and cities of similar characteristics in terms of economy and population. Of course, some necessary adjustments were required and outliers were omitted. The results are summarized in Table 2, where all the parameters with the values selected for the economic analysis of the present paper are presented.
Table 2. Summary of the values of the parameters selected for the present study.

| Indicators                        | Valuation (€2018)       |
|-----------------------------------|-------------------------|
| Value of Travel Time              | 9.46 €/hour             |
| Vehicle operating cost            | 0.307 € / vehicle-km    |
| Value of accident costs           |                         |
| Death: 1,121,060 €                |                         |
| Seriously Injured: 146,503 €      |                         |
| Slightly Injured: 11,221 €        |                         |
| Air pollution cost                | 0.0061 € / vehicle-km   |
| Noise pollution cost              | 0.013 € / vehicle-km    |

The quantification of benefits, and more specifically the calculation of the time travel hours saved and the kilometers of private vehicles saved for each benefit category were based on the assumptions of the ex-ante cost-benefit analysis [7] and also on the actual data regarding ridership and ticket fares from the operator (STASY S.A.). In addition, the indicators for the calculation of the accident’s reduction were taken from the study “Extension of Athens Metro Line 3, section Aghia Marina (formerly Chaidari station) – Piraeus”, conducted by SYSTEMA MELETITIKI LTD [14]. According, to the ex-ante analysis, the travel hours saved start at 705,000 h per year in the 1st year of operation (2014) and reach a maximum value of approximately 5,000,000 h in the 20th year (2034), remaining constant for the subsequent period. Regarding the vehicle-km figures that can be saved by the metro development, the total distance avoided starts from 5.6x10^3 km per year in the 1st year of operation and reaches the value of 32 x10^3 km in the 20th year.

As far as the daily ridership is concerned, the data reveal that the initial estimates of ATTIKO METRO S.A. that were also used in the ex-ante analysis, were on the conservative side. More specifically, the actual average daily ridership of the new station of Aghia Marina has proved to be higher by 30 - 40%, compared to the initial estimates. Furthermore, it displays a trend of steady increase over the years, ranking the Aghia Marina station in the top 15 Athens metro stations based on average daily ridership. This fact serves as proof that the station was successfully integrated in the whole underground metropolitan railway system and is gradually becoming more popular among users for their daily transit. In 2014 the average daily ridership was measured at more than 13,500 passengers compared to the 8,000 passengers as estimated in the initial study. The same applies for the subsequent years. The figures for the average daily ridership in 2017 and 2018 were 17,500 and 16,850 passengers respectively, in contrast with the initially forecasted numbers of 10,600 and 11,600. Of course, it should be indicated that since 2017 the enforcement of stricter fare control policies took place, aimed at reducing free-riders resulted in a significant increase in the measured ridership and had, of course, a positive impact in the revenues from ticket fares.

For the economic analysis the assumptions are summarized as follows:

- The financial prices of investment cost, operating and maintenance cost and residual value were converted to economic prices using specific conversion factors, in order to reflect the economic opportunity cost.

- All economic cash flows were discounted with a 5% discount rate, according to the European Union Project Evaluation Guide [13].

- The analysis is conducted in constant prices (Euro) 2018. Current prices are converted to constant prices based on published ELSTAT data.

The economic indicators for the ex-post economic analysis are summarized in Table 3. As it can be seen the project is economically feasible because it has positive ENPV of around € 340 million, and an EIRR
figure almost 3 times the corresponding economic discount rate. Furthermore, a significantly high B/C ratio of 4.4 is recorded indicating that the project is highly beneficial.

Table 3. Results of economic analysis (€ 2018).

|                | 2006  | 2009  | 2013  | 2014  | 2019  | 2025  | 2030  | 2036  | 2043  |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| **ENPV (%)**   |       |       |       |       |       |       |       |       |       |
| **Construction** |       |       |       |       |       |       |       |       |       |
| Investment Cost | -73.560 | -9.966 | -10.653 | -2.487 | -1.114 | 0     | 0     | 0     | 0     |
| Maintenance costs | -8.307 | -3.57 | -6.57 | -7.91 | -9.31 | -1.113 | -1.346 |       |       |
| Personnel costs | -7.614 | -7.32 | -7.32 | -7.32 | -7.32 | -7.32 | -7.32 |       |       |
| Revenues | 42.556 | 1.640 | 4.157 | 4.545 | 4.896 | 5.354 | 5.942 |       |       |
| Gross Profit | 26.634 | 551   | 2.788 | 3.022 | 3.234 | 3.510 | 3.864 |       |       |
| Depreciations | 56.801 | 5.049 | 8.288 | 8.536 | 3.736 | 1.37 | 0     | 0     | 0     |
| Taxable income | 30.167 | -5.049 | -8.288 | -7.985 | -8.47 | 2.886 | 3.234 | 3.510 | 3.864 |
| Taxes paid | -5.622 | -837  | -837 | -938 | -1.018 | -1.121 |       |       |       |
| Net profit | 35.789 | -5.049 | -8.288 | -7.985 | -8.47 | 2.049 | 2.296 | 2.492 | 2.743 |
| Residual value | 5,434 |       |       |       |       |       |       |       | 34,998 |
| **Financial CF** | -47.114 | -9.966 | -10.653 | -2.487 | -5.63 | 2.788 | 2.185 | 2.296 | 2.492 |
| Time travel savings | 315,880 | 6,669 | 20,419 | 35,545 | 42,420 | 47,920 | 47,920 |       |       |
| Car operational savings | 66,907 | 1,739 | 4,462 | 7,457 | 8,819 | 9,908 | 9,908 |       |       |
| Accident savings | 815 | 25 | 55 | 85 | 100 | 109 | 222 |       |       |
| Air pollution savings | 1,338 | 34 | 87 | 146 | 172 | 194 | 387 |       |       |
| Noise pollution savings | 2,899 | 74 | 189 | 316 | 373 | 420 | 838 |       |       |
| **Social Benefits CF** | 387,838 | 8,542 | 25,213 | 43,548 | 51,884 | 58,550 | 59,274 |       |       |
| **Financial & Social CF** | 544,724 | 31,466 | 31,466 | 41,847 | 54,547 | 61,847 | 61,847 | 96,716 |       |
| **ENPV (€10^3)** | 540,724 |       |       |       |       |       |       |       |       |
| **ERR (%)** | 15.95 |       |       |       |       |       |       |       |       |
| **BCR** | 4.4 |       |       |       |       |       |       |       |       |

From the benefits, it is found that time travel reduction and the respective benefits as well as the savings obtained from the avoidance of car operational costs are the most important benefits from the development of the metro Line 3 extension (Figure 2).

Figure 2. Breakdown of the social benefits gained from the development of the metro project.

5. Conclusions – Discussion of the results
The western expansion of Line 3 “Egaleo-Aghia Marina” is expected to have a positive impact from a social perspective, owing to travel time and vehicle operational cost savings, air pollution reduction,
better road safety, in terms of accident decrease, as well as employment opportunities during the construction and the operation of the project. The results of the social cost benefit analysis clearly illustrate that if the project was examined on purely financial criteria, the decision making process would probably reject the construction of the extension metro project. However, the monetary valuation of the social and environmental benefits of the project render the project beneficial and desirable from a social point of view. Furthermore, it is worth noticing that the analysis did not include all the social and environmental benefits stemming from the operation of the project. Benefits like land and house prices, as well as rents increase owing to the economic and commercial growth in the neighboring areas would give a surplus value on the outcome.

This particular expansion has also been the subject of an ex-ante SCBA in the past [7]. The results of that paper are in line with the ex-post analysis presented here. The project in the ex-ante analysis was also found to be not feasible in the financial analysis and only with the introduction of the monetary social and environmental benefits did it became feasible.

The main differences between the ex-ante and ex-post approaches are as follows:

- The Aghia Marina station operated in 2014 and not in 2010 as was anticipated in the ex-ante evaluation.
- The station's revenue in the ex-post analysis does not include commercial revenues, in contrast with the forecast from the ex-ante evaluation, where commercial revenues accounted for 12% of the total revenues.
- A discount rate of 7% was used in the ex-ante financial analysis and 4% in the ex-post evaluation (in accordance with the European Union's Guide to Cost-Benefit Analysis [13]).

The decision-making process with regards to underground or aboveground alternatives should take into account all the ensuing short-term and long-term social and environmental benefits of large infrastructure underground projects. Social cost benefit analysis and environmental economy constitute valuable tools in investment project appraisal. They facilitate the decision-making processes and lead to sound and socially beneficial decisions. Ex-post evaluation is vital to determining whether the planned benefits of a project have been met or not. There is widespread agreement among both planners and decision makers of the need for ex post evaluations and yet, they remain rare in most countries. There is an increasing range of studies focusing on individual parameters included in the original CBA and some countries are also routinely carrying out full ex post CBAs. Comprehensive evaluation frameworks aiming to assess the projects' wider effects including their strategic performance are, however, not common.

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