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RESEARCH ARTICLE

Cost benefit analysis and ex-post evaluation for railway upgrade projects

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Abstract

Infrastructure investments have an important role in a country´s development, but the scarcity of resources in the current economic situation (world crisis) emphasizes the need for decision support tools. Several research projects have previously been carried out in order to improve the currently-used Cost-Benefit Analysis (CBA) methodology. CBA is a widely accepted and used decision support tool, even if it has its own shortcomings and drawbacks.

The objective of this work is to assess the current limitations of CBA methodologies applied in Europe using cases in Hungary. It also collects and summarizes the main research and findings in the field of ex-post evaluation. Two Hungarian railway upgrade projects were evaluated economically. The change of CBA methodology had a more significant impact for the economic indicators, than the changes of the input parameters.

In addition to the economic analysis, the financial losses were evaluated, since these projects caused significant disturbances for the operations during the construction period. There is a need for more ex-post evaluations carried out in railway upgrade projects in order to better understand their impacts.

Keywords

ex-post evaluation · economic cost-benefit analysis · railway upgrade · CBA methodology · drawbacks · traffic disturbance during construction

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1 Introduction

As Cost-Benefit Analysis (CBA) is an applied social science, it is mainly based on assumptions. Therefore a CBA can be only as good as its assumptions are. Infrastructure investment projects regularly experience cost and time overruns. Research led by Flyvberg has suggested that misrepresentation and optimism bias are primary causes for overruns [6]. Current researches are mainly focused on new construction and limited attention was devoted to the infrastructure upgrade projects and their impacts on the cost, schedule and traffic. The upgrade works can cause significant disturbance to the existing infrastructure normal operation, especially in rail projects.

The objective of this article is to present the current limitations of CBA methodologies applied in Europe [12, 13] using cases in Hungary. It will also collect and summarize the main research and findings in the field of ex-post evaluation.

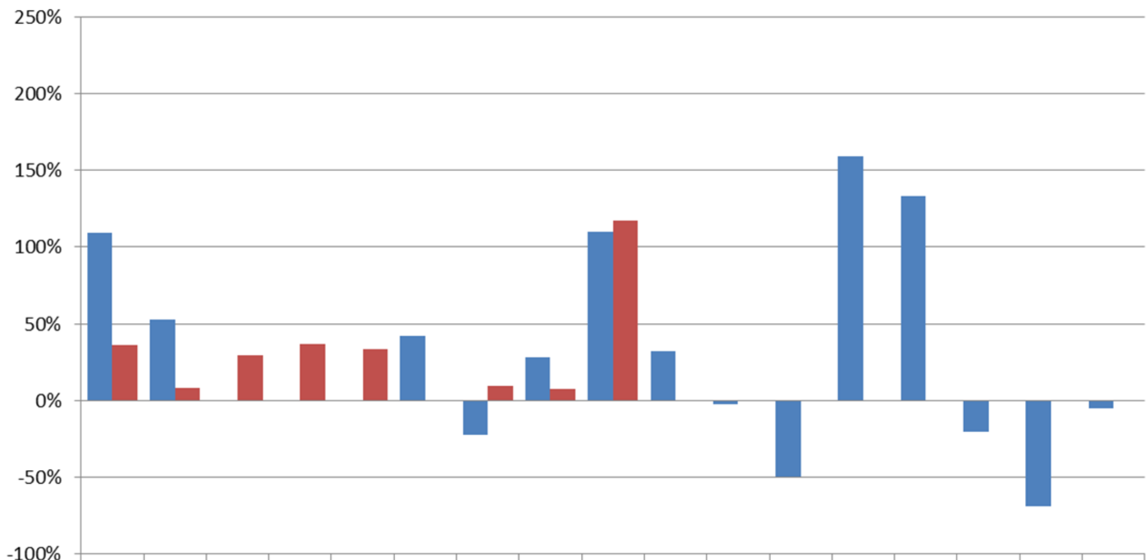
Two Hungarian railway upgrade projects were evaluated economically. In each selected project, the original ex-ante CBA will be recreated and a new ex-post evaluation will be implemented based on the available information. The ex-ante and ex-post results will be compared and further conclusions will be drawn. In addition to the economic analysis, the financial losses were evaluated, since these projects caused significant disturbances for the operations during the construction period.

Travel time variability was examined closely. Calculations were made through a case study in order to determine the importance of this impact.

A concise literature review of the CBA methodology and the limitation of CBA can be found in earlier studies [10, 11], therefore it is not repeated in this article.

2 State-of-the-art ex-post evaluation results

The existing literature of ex-post evaluation devoted high importance of cost overruns and delays. The main reasons of cost overruns are the modification of the technical content of the projects, some sort of technical difficulties, wrong cost estimation during the preparation phase and delays of the projects. These four reasons caused the cost overruns in more than half of the cases [4]. Cost overruns occur in all types of projects,



	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17
Ex-ante old --> Ex-ante new	109%	52%	0%	0%	0%	42%	-22%	28%	110%	32%	-3%	-50%	159%	133%	-20%	-69%	-5%
Ex ante new --> Ex-post new	36%	8%	29%	37%	33%	0%	10%	7%	117%	0%	0%	0%	0%	0%	0%	0%	0%

Fig. 1. NPV changes, source: [10]

90% of projects have some cost escalation. The average cost overrun is 28%. In the case of railway projects the picture is even worse, since the average cost overrun for rail investment projects is 45% with a standard deviation of 38% [7].

The delay of the project has also significant impact of the project indicators. The two main reasons for the delays are some sort of technical difficulties and external factors. These two factors together reported as the main reason in more than half of the cases [4].

Optimism bias is a phenomenon which exists not only in transport, but also in every large scale infrastructure projects. More advance countries in the field of project appraisals therefore developed techniques to deal with it [8].

In the same time less research was carried out concerning the problem of traffic disturbance during upgrade projects. Especially for rail infrastructure it can be a problem, since the construction (modernization) activities can disturb the daily operation on the line. The railway companies all over the world have significant experience and existing know-how to carry out maintenance activities during low traffic periods and these activities cause almost no problem for the operation. Even if these activities require closure of the track, these know-how can help to estimate the time and cost of the maintenance quite well. However, the railway companies have limited experience about the large scale upgrade projects, which often comes with complete reconstruction of the track. These upgrades are often cause significant delays for the operating trains. Due to the limited experience these projects often suffer from delays and cost overruns. Additionally to that the trouble caused for the passenger (delays, changes to replacement busses etc.) often results traffic loss. This traffic loss can be seen as temporary financial loss, but a passenger who switches back to his car, has a limited probability to switch back to train.

3 Ex-post evaluation through case studies

Detailed economic ex-post evaluations had been carried out for the following two railway line reconstruction projects:

1 Upgrade of the Budapest–Cegléd–Szolnok line;

2 Modernization of the Sopron–Szombathely–Szentgotthárd railway line.

In this article the ex-post evaluation results of the Budapest–Cegléd–Szolnok line upgrade have been presented. The first part of this line functioning as commuter railway line of Budapest, but it also serves as a part of the IV international Helsinki corridor [2]. There were three separated spreadsheet models created. The first one was in order to recreate the ex-ante CBA with the old methodology, the second one to create the ex-ante CBA with the new methodology and the third one to create the ex-post evaluation. The main results are the changes in Net Present Value compared to the ex-ante old CBA. The method for this calculation consists of several parts. The first part is to compare the ex-ante old methodology with the ex-ante new one. The second one is to compare the ex-ante new with the ex-post evaluation. In both cases the factors, which has effect on several costs or benefits first change (e.g. evaluation period or traffic) was modified, than the costs and benefits were compared. The changes and causes can be summarized as the followings (Fig.1.):

- Evaluation period (E1): The evaluation period change from 25 years to 30 years in line with the Hungarian Guide. These change affected also the result of the ex-post evaluation.

- Discount rate (E2): The economic discount rate was changed from 6% to 5.5%. Therefore the NPV changed between ex-ante old and ex-ante new. These change affected also the result of the ex-post evaluation.
- GDP increase rate (E3): The actual GDP values are different than the planned one. The GDP has an impact on the change of the economic specific cost in real value. Since this is not a methodological change it has only impact between ex-ante new and ex-post.
- Traffic change (E4): The actual traffic figures are different than the expected ones, therefore the NPV decreased significantly from the ex-ante new to the ex-post case. The traffic has significant impact on the NPV, since most of the economic benefits are connected to the traffic in both models.
- Investment cost and schedule (E5): The investment has some delays, but the investment cost in non-discounted values is almost identical with the planned one. The delay and the slight change in the investment cost cause reduction in the discounted costs between the ex-ante new and the ex-post. Since there was no methodological change in this item, the ex-ante old and new ones are identical.
- Operation and maintenance cost (E6): The reduction in the operation and maintenance cost are high, since the old method did not identified the replacement cost separately.
- Replacement cost (E7): There is large methodological change, since in the old methodology the replacement cost was not calculated at all. The change between the ex-ante new and ex-post cases was because of the change in the investment cost and the lifecycle of each item.
- Residual value (E8): The calculation of the residual value was more sophisticated in the new methodology, therefore a large increase between the ex-ante old and new. The change between the ex-ante new and ex-post cases was because of the change in the investment cost.
- Time cost savings (E9): The most significant change in all the factors was the travel time savings. The significant increase in the Value of Time caused a significant increase between ex-ante old and the ex-ante new. The replacement of assumption with real travel times caused also a large increase in the NPV between ex-ante new and ex-post.
- Road accident cost savings (E10): Due to the methodological change (both the accident rates and the specific costs) there is an increase in the NPV between ex-ante old and ex-ante new. Since the change in the traffic already calculated there was no change between the ex-ante new and ex-post.
- Rail accident cost savings (E11): It was not considered any rail accident cost reduction in the new methodology, therefore the NPV slightly decreased between the ex-ante old and ex-ante new. Since the change in the traffic already calculated there was no change between the ex-ante new and ex-post.
- Air pollution reduction (E12): The changes in the methodology of the environmental cost savings calculation caused change in the NPV between the ex-ante old and ex-ante new. Since the change in the traffic already calculated there was no change between the ex-ante new and ex-post.
- Noise reduction (E13): The changes in the methodology of the environmental cost savings calculation caused change in the NPV between the ex-ante old and ex-ante new. Since the change in the traffic already calculated there was no change between the ex-ante new and ex-post.
- Climate change (E14): The climate change was not calculated in the old methodology; therefore it caused an increase in the NPV between the ex-ante old and ex-ante new. Since the change in the traffic already calculated there was no change between the ex-ante new and ex-post.
- Road operating cost savings (E15): The calculation methodology of the road operating cost savings was one of the factors which were decreased the NPV between the ex-ante old and ex-ante new. Since the change in the traffic already calculated there was no change between the ex-ante new and ex-post.
- Economic development (E16): The new methodology did not consider the economic development as economic benefit, therefore NPV decreased.
- Employment creation (E17): The new methodology did not consider the employment creation as economic benefit, therefore NPV decreased.

The above mentioned cases clearly demonstrated the development of the Hungarian Cost-Benefit Analysis guides [10]. In the early 2000 there was an oversimplified Guide which just laid down some specific proposals for the professional. This Hungarian Guide was based on the European one [5]. In these times the professionals used it as an advice and the interpretation of it were often different. The original CBA of Budapest–Cegléd–Szolnok line upgrade was based on this. A more coherent and mandatory Guide [12] was developed for the 2007-2013 EU programing period, after 2007 to use this guide was mandatory for every EU funded infrastructure investment project. The CBA of the Sopron–Szombathely–Szentgotthárd railway line modernization project was based on this guide. The latest Hungarian guide [13] is an upgrade of the previous one, there were no big structural changes, but all the specific costs were recalculated. The financial analysis review of the Budapest–Cegléd–Szolnok line upgrade [3] and all the ex-post calculation of this study were based on this current Hungarian guide.

The results of the first case study show structural changes between the different guides. The economic development and the impact for employment during construction are no longer be added to the economic benefits, at the same time the travel time savings have a far higher share among the economic benefits. In this methodological jump the Hungarian professionals was forced to use the specific cost of the guide, even if these costs might be overestimated.

The results of the first case study with the comparison of the second case study underline the assumption, that a structural change in the methodology has more impact on the results, than a slight miscalculation of some parameters (e.g. GDP, discount rate).

Very important findings can be seen of the second case study: based on the ex-post evaluation this project might have not been got financed under the Transport Operative Program. One of the several criteria of the financing is that the Economic Internal Rate of Return should be higher than the used economic discount rate. In other worlds the discounted economic benefits should be higher than the discounted economic costs. In the case of the Sopron–Szombathely–Szentgotthárd line modernization project this difference originated from two major changes: travel time estimation and O&M cost estimation. During the planning stage the achievable running time reductions were overestimated. This overestimation has a technical reason: the trains are not allowed to run with 160 km/h since the ETCS and GSM-R systems are not yet implemented in the Hungarian network, although based on the layout of the track and the trains this speed can be possible. This was a high risk during the project which the owner of the project had no influence on. The other change is the calculation method of the replacement cost: the ex-ante CBA underestimated the replacement cost, since it was an assumption of the project owner. In the ex-post CBA the replacement cost was calculated based on the useful lifecycle of the infrastructure.

4 Financial impact of traffic disturbance during construction

Only the CBA of the second case was taking into account the traffic disturbance during construction and even this is just calculated the economic cost of it. In the same time it can be a high financial loss associated to this, since the passengers who shift towards car are hardly sit back to train. Railway line renewal projects usually introduce travel time increase during construction in the affected line. Some cases not only a travel time increase had been introduced, but also additional discomfort such as the passengers had to change to replacement busses many times. These facts together can lead to a drastic drop of passenger numbers, which directly related to financial loss of train operators.

The Hungarian case studies show very different results, since the methodology of ex-ante CBAs were different. In the case of Budapest–Cegléd–Szolnok line upgrade the authors of the ex-ante CBA did not take into account any traffic loss due to the work, but as the facts show quite considerable decrease can be realized (Fig.2.).

These traffic loss caused around €5 million discounted financial loss of the operator which is equivalent about 5% of the investment cost. This financial loss was never foreseen and accounted in the ex-ante analysis.

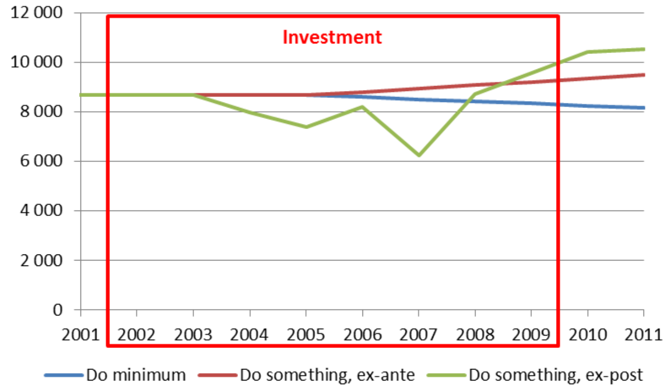


Fig. 2. Passenger traffic between 2000 and 2011 on Budapest–Cegléd–Szolnok line, Source: [10]

In the other hand the Sopron–Szombathely–Szentgotthárd modernization project ex-ante CBA dealt with the traffic loss during construction . The authors of the study assumed a significant passenger decrease which was as an overestimation equivalent of €70 thousand. The total financial loss due to the inconvenience during implementation of the upgrade had been calculated as around €0.2 million which is equal about 0.1% of the investment cost.

These numbers can provide a good indication about the magnitude of this type of financial loss. Naturally these conclusions are specific for these cases only, given the limited data availability during the preparation of this study. Based on these Hungarian examples it can be stated that this topic is worth further scientific investigation even with a bigger sample and a more complete dataset.

5 Economic impact of travel time variability

This chapter is focused on the economic analysis of travel time variability based on the methodology and findings provided by earlier studies [10, 11]. Research suggests that the reliability of travel time should be a quality parameter of the rail services [8]. This field of economic analysis is only researched in the well-developed western European countries, where the methodology of CBA advanced (e.g. Sweden, England and Denmark). For this type of analysis large dataset required, which were not available in the Hungarian State Railways only in GYSEV. Given this fact the calculation were made only the Sopron–Szombathely–Szentgotthárd railway line modernization project.

The mean and the standard deviation of the lateness were calculated based on the VIHAR system of GYSEV. These data includes all trains and its delays for 2009–2011. According to the proposed methodology the early arrivals were treated as on time arrivals. In the do-minimum case the 2007 data was used and it was assumed that it stays constant during the evaluation period. In the do-something case the 2011 data was used for the remaining evaluation period. In this case study the cancelled operations were not taken into account since there was no such data available.

The planned delay was calculated based on the data available at. An average delay was calculated based on a regular share of the passengers between different types of services. This average delay was multiplied by the number of days and the number of passenger per days.

The total planned delay was calculated in hours per year. The lateness factor of 2.5 was used in order to calculate travel time equivalent and it was multiplied with the Value of Time. The unplanned delay was calculated based on both the mean lateness and its standard deviation. These statistical parameters were calculated based upon data extracted the VIHAR system of GYSEV. The unplanned delay was calculated with the lateness factor of 2.5 and reliability ratio 1.4. In order to get the economic benefit these hours per year were multiplied with the Value of Time.

The total economic costs (negative benefits) are smaller in the ex-post case which means that the author of the ex-ante CBA slightly overestimated the impact of the construction (Tab.1.).

Tab. 1. Economic benefits of the Sopron–Szombathely–Szentgotthárd railway line modernization project for TTV during construction [11]

Economic cost during construction [€million]	Ex-ante old	Ex-ante new	Ex-post
Passenger time savings of existing passenger	-14.56	-13.46	-0.91
Planned delays reduction	0.00	0.00	-4.54
Unplanned delay mean reduction	0.00	0.00	-1.60
Unplanned delay standard deviation reduction	0.00	0.00	-5.42
Total economic benefits	-14.56	-13.46	-12.48
Total investment costs	168.94	168.94	179.52

In the operating period there is no such thing as planned delay. The travel time variability reduction was calculated due to the new equipment, signaling and higher maintenance of the service. The mean lateness and standard deviation of it was estimated as the same as the 2011 data. This is a quite rough estimation and it is might not be the best, but without more available data it can be acceptable. The economic benefit was calculated at an amount of €30.916 million which is equal up to 15 percent of the investment cost.

The cumulated benefits – including construction and operation periods – have a positive impact on the NPV.

The travel time variability (8%) as a new economic benefit has a share equivalent to some other benefits such as: residual value (2%), climate change (3%) and noise reduction (2%). Only three types of benefits have a higher impact: travel time cost savings (60%), road accident cost savings (9%) and road operating cost saving (10%). Based on this illustrative example results showed that the benefit of Travel Time Variability reduction has a same magnitude as the cumulated environmental benefits, the cumulated accident cost savings and the road operating cost savings (Fig.3.). Therefore it can be a significant effect for the results of any economic analysis.

This illustrative example demonstrates the importance of this

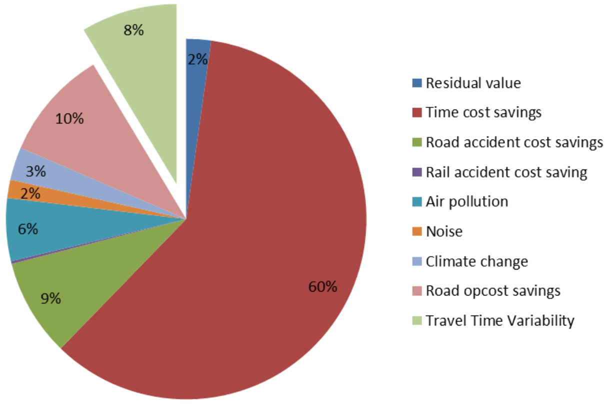


Fig. 3. Economic benefit of the Sopron–Szombathely–Szentgotthárd railway line modernization project including TTV [11]

field, since the overall benefit has the same magnitude as other already calculated ones (e.g. cumulated environmental benefits, the cumulated accident cost savings and road operating cost savings).

At the same time this case study clearly demonstrates the limitation of this method, since the travel time variability after construction was a very rough estimation. The investment was finished in 2010, therefore a dataset with more years of delays were not available. This situation can be changed since the Hungarian State Railways started publish the delays of each train in Hungary and started store these data. With these data in a couple of years a comprehensive dataset can be set up and more thorough statistical analysis can be made in order to determine the pattern of travel time variability.

6 Conclusions

Two Hungarian railway upgrade projects were post-evaluated economically. The two projects have different owners and the characteristics of the lines are largely different also. The analysis shows that change of CBA methodology (e.g. specific environmental costs, Value of Time) has a more significant impact for the economic indicators, than the changes of the input parameters (e.g. traffic level, GDP). As the two ex-ante CBA were created based on different CBA methodology these impacts can be seen more easily. It has to be highlighted that based on the ex-post evaluation one of the project might not got funded, since the economic indicators did not meet the threshold.

The two above mentioned Hungarian projects were analyzed further. In addition to the economic ex-post analysis, the financial loss was evaluated. The results of the two case studies were different, therefore further investigation of this field is recommended. Calculations were made through a case study in order to determine the importance of the impact. It can be stated that it can be a significant effect for the results of any economic analysis. There is also room for improvement on the macroscopic and route choice modeling including travel time variability [1, 9].

There is a large need for more ex-post evaluations carried out in railway upgrade projects in order to better understand the impacts.

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