New Methodology for Railway Infrastructure Evaluation and its Impact

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Abstract. The paper is focused on the evaluation of the economic efficiency of investment projects in the area of railway structures in the Czech Republic. The economic evaluation of projects of the transport structures including the railway structures has in recent years undergone through significant changes resulting into the final form of the united resort methodology of the Ministry of Transport of the Czech Republic, which from the methodological point of view covers the economic evaluation of all projects of transport structures. The main objective of the paper is to evaluate the impact of methodological changes in the financial and the economic evaluation of projects of railway structures. New methodological approaches can have the influence on economic results of monitored investments. The attention is paid to all aspects influencing the economic efficiency of the projects, especially the issues of investment and operational costs, costs for the trains operation and whole society benefits in the form of time savings, savings resulting from externalities a savings resulting from increased safety on railway are solved. From the methodological point of view, the paper is focused on the comparison of the approach to economic evaluation according to the previous methodologies specialised exactly on projects in the railway infrastructure with the approach according to the new methodology. The new resort methodology unifies specific parts of the analysis for all types of transport constructions and at the same time defines partial methodological approaches intended for particular transport modes. Within the previous methodologies the “transition methodology” valid from the half of 2016 to the acceptation of new resort methodology in November 2017 is also considered. In the frame of research works, the identified differences are also analysed. Impacts of methodological changes are presented on the case study of the model railway construction, from which the significant decrease of values of criterial indicators declaring lower economic efficiency is evident. Impacts are solved individually for particular parts of the financial and the economic analysis. From the case study is evident that all aspects included in the economic evaluation result to the decrease of the total economic efficiency of the investment project on the railway connected with the changes in methodology, however the changes in travel time savings and savings on externalities are the most important.

1. Introduction

The paper is focused on the economic evaluation of projects of railways structures in conditions of the Czech Republic, mainly then on the influence of changes in methodological approaches on results of the economic analysis. During the November 2017, the Ministry of Transport of the Czech Republic (MOT) approved the Departmental Guideline for the Evaluation of Economic Effectiveness of Transport Construction Projects (Departmental Methodology). Consequently, the Implementing instructions for the evaluation of the efficiency of projects of transport infrastructure were issued by MOT.
Implementing instructions assess the unified procedure of investors in evaluation of economic efficiency of following projects financed from public budgets:

- Important water structures in traffic,
- Road and highway structures,
- Railway structures,
- Multimodal transport,
- City rail transport,
- Intelligent transport systems.

The Departmental Methodology so consolidates procedures of the economic evaluation of previously mentioned projects into one methodology.

The subject of the paper is to conclude basic differences in the field of financial and economic efficiency in railway infrastructure and on the case study to quantify impacts of these changes on results of the economic evaluation.

2. Present state references

The efficiency of investment projects in the field of the railway infrastructure is one of key factors influencing the support of the project for the financing from public resources. The basic approach for the evaluation of the efficiency of projects in the transport, including and the railway, infrastructure is the Cost-Benefit Analysis (CBA). The key groundwork for the CBA elaboration is currently the Guide to Cost-Benefit Analysis of Investment Projects issued in 2014 by the European Commission [1]. This text includes, instead the general determination of the CBA principles, also practical case studies representing specific approaches used in elaboration of various kinds of projects, including projects of the railway infrastructure, carrying out. Following information stated in the introduction of the paper, in the case of the economic evaluation of projects of the transport infrastructure in conditions of the Czech Republic it is also necessary to mention next methodological groundworks. Within the projects of the railway infrastructure it is mainly about “The Implementing Instructions for Evaluating of the Economic Effectiveness of Projects of Railway Infrastructure” [2], issued by the Ministry of Transport of the Czech Republic. These instructions were in the mid-year of 2016 supplemented by the “The methodology for evaluation of economic efficiency and ex-post evaluation of costs and benefits of railway infrastructure projects, road infrastructure projects and significant water ways in traffic (hereinafter the “Transition Methodology””) [3]. All these methodological groundworks were, how mentioned in the introduction, in November 2017 replaced by the “Departmental Guideline for the Evaluation of Economic Effectiveness of Transport Construction Projects” (hereinafter the “Departmental Methodology”). [4] Except methodological groundworks, the efficiency of transport structures is the topic of many next publications. Socio-economic impacts and risks of big projects and megaprojects including projects of railway structures are solved in detail in the monography „Megaprojects and Risk“ by Bent Flyvbjerg [5], who on many case studies presents specifics and impacts of big infrastructure projects. The paper [6] deals with the importance of the railway infrastructure and its impact on the national economy in Germany, where mainly the correlation between working railway system and the Gross Domestic Product is looked for. The issue of the evaluation of benefits connected with projects of railway transport, mainly regarding the informatization of the railway infrastructure, is in detail solved within the reference [7]. In the case of the railway infrastructure, also the efficiency of the construction in the sense of „the Lean Construction“ is solved. This issue is discussed in the reference [8]. The efficiency of the carrying out of construction orders in the area of the transport infrastructure has also the significant importance on the economy of the supplying company [9] and on the creation of its economic result [10]. The railway infrastructure should be understood in the context of the whole traffic system. The reference [11] pays attention on the importance of the railway transport within the intermodal transport. The support of the decision making process of the financing of “urban projects” is solved by the international team in the reference [12]. Socio-economic impacts on passengers are consequently discussed in the reference [13].
3. Methodology

Research works are focused on the monitoring of differences in resulting values of indexes of the economic efficiency of projects on railway infrastructure induced by the change of methodological approaches for the evaluation. In the field of the transport infrastructure, the economic evaluation is usually carried out in the form of the Cost-Benefit Analysis (CBA). The CBA is the analytic tool for the evaluation of economic advantages or disadvantages of investment decisions based on the comparison of their costs and benefits. The objective of the CBA is to evaluate the contribution of projects to the change of the level of the economic welfare. The CBA evaluates the construction from the long-time horizon as well. The evaluation period is in the case of railway structures 30 years and includes the phase of realization and the phase of operation.

Within the CBA the differences between the project variant and the variant without project are evaluated. The difference between variants then defines the final benefit of the project variant, which can be positive or negative. It is the incremental approach, which is based on following principles:

- the variant without project must to describe, what would happen in the case of non-existence of the project. This scenario works with estimations of all cash-flows related with operations within the project;
- the project variant includes cash-flows for situations proposed within the project. All investments, financial and economic costs and benefits flowing from the project are taken into account;
- the CBA respects only the difference between cash-flows in the project scenario and scenario without project. Financial and economic indexes of efficiency only according to incremental cash flows are calculated.

Incremental cash flows in particular years of the evaluation period create project cash flow. The negative cash flow means the cost for the investor or the society, the positive cash flow means their profit or the saving. These values, in order to assess the total net benefit of the project are discounted and then summarised. The total efficiency of the project by specific indicators is measured. Economic indicators are Economic Net Present Value (ENPV) expressed in currency units, the Economic Rate of Return (ERR) and the Benefit-Cost Ratio (BCR), which allows the comparison of competitive projects or alternatives.

The CBA allows the evaluation of the influence of the project on the society as a whole due to the calculation of economic efficiency indicators, what enables to judge the expected change of the welfare level. The objective of the economic evaluation is to determine, whether the construction is suitable for the realisation and at the same time is eligible for the financing from public resources.

The economic evaluation consists from the economic analysis, the financial analysis and the risk analysis. The financial analysis from the position of the owner of the infrastructure / investor is carried out. In the case of railway structures, it is mainly the Railway Infrastructure Administration. The economic and financial analysis evaluates the efficiency using the CBA approach. The economic analysis evaluates whole society benefits of the investment. The last part of the economic evaluation is the risk analysis, which includes the risks identification, the sensitivity analysis and the quantitative and the qualitative analysis.

The methodology used within the paper is based on the comparison of approaches to the economic evaluation of projects of the realisation the railway structures defined in previous methodologies (references [2] and [3]) and new Departmental Methodology ]4]. Detected differences are quantified firstly in the unit expression and in the next part of the paper through the case study of the model project of the railway construction realisation.

Differences in methodological approaches are within the financial analysis examined in:

- investment costs calculation,
- the residual value assessment,
- costs for serviceability assessment,
- costs for operation assessment,
- incomes from users’ assessment and
• other incomes assessment.  
Within the economic analysis are examined differences in:
• factors of conversion,
• costs for the trains operation assessment,
• benefits from the travel time savings for passengers and goods assessment,
• costs for roads and highway operation assessment,
• externalities (decreasing of accidents, noise, air pollution and climate changes) assessment.

4. Results and discussion
Results of comparison of approaches for the economic evaluation of projects of the realisation of railway structures defined in previous methodologies (references [2] and [3] and in new Departmental Methodology [4] lead to the identification of key areas, which influence the change in the economic evaluation the most. The comparison is divided into area of the financial analysis and the area of the economic analysis.

4.1 Financial analysis
The first inputs, which generally have the important influence on the economic evaluation, are investment costs. Investment costs are defined according to the technical solution of the construction and include costs for the preparation and project documentation, annexations and acquisitions of lands, constructions, technological sets, the technical assistance, the promotion, the technical supervision and the reserve. Total investment costs without the reserve and VAT enter the economic evaluation in particular years of the realisation.

Investment costs are not dependent on the selected methodology, but on the technical solution. From this reason, this input is the same for any chosen evaluation methodology. In 2016, the Ministry of Transport of the Czech Republic issued the „Instructions for the valuation of railway structures on the degree of the feasibility study“, which adjusts the valuation of investment projects in the phase of the feasibility study. This methodological approach unified unit prices for the calculation of investment costs for all constructions evaluated within the feasibility study.

The next input into the financial analysis is the residual value. If the estimated economic lifetime of the structure is longer than 30 years (reference period), the residual value is calculated like the net present value of cash flows from the residual years of the construction lifetime. The expected economic lifetime of the construction within the evaluated investment is assessed according to the object composition as a weight average (weights are investment costs for particular types of objects) of lifetimes of particular objects. The approach for the residual value assessment retained within new Departmental Methodology without changes, the big change was connected with the change of the methodology from 2013 [2] to the methodology from 2016 [3].

Costs for the serviceability include costs for maintenance and repairs of the infrastructure. In the case of the project variant, they can also include costs for re-investments of the equipment with the lifetime shorter than the evaluated period. Costs for the serviceability are not dependent on the chosen methodology. Within the project variant, these costs are dependent on the technical solution, within the variant without project these costs come out from the present state of the relevant infrastructure and planned repairs.

Costs for operation include costs for employees doing the service on the railway transport route and are calculated as a multiplication of number of workers on specific position and average costs connected with their remuneration. Average unit costs for operation for all professions have fallen within the price level 2017 by 4.7 % in comparison of the Departmental Methodology and the previous valid methodology. In the project evaluation, it is possible to expect slightly decreased benefit from savings from costs for operation.

Incomes from users of infrastructure are created from the charge for the railway route usage and incomes from the sale of the capacity on the railway route. These incomes are assessed according to the transport performance realised on the railway infrastructure, the railway category and appropriate cost
fee. By nature, they are not dependant on the selected methodology, but on the price policy of the administrator of the infrastructure, which is presented annually in the “Declaration about the railway”.

Other incomes can be created e.g. by incomes from new commercial areas and they are for each projects assessed individually. Other incomes are not dependant on the selected methodology.

4.2 Economic analysis

Basic inputs for the determination of cash flows for the economic analysis are following items of the financial analysis, which are for next calculations modified by factors of conversion (fiscal correctors):

- investment costs,
- residual value,
- operation costs of infrastructure.

All factors of conversion were within the Departmental Methodology decreased comparing to previous methodologies. It means that cost item enters the economic analysis with lower weight. See the detail in the table 1.

| Description                     | Previous methodology | Departmental methodology | Difference |
|---------------------------------|-----------------------|--------------------------|------------|
| Investment costs                | 0.93                  | 0.801                    | -0.129     |
| Serviceability                  | 0.93                  | 0.795                    | -0.135     |
| Re-investments                  | 0.93                  | 0.856                    | -0.074     |
| Operation of infrastructure     | 0.82                  | 0.601                    | -0.219     |
| Operation of trains             | 0.93                  | 0.812                    | -0.118     |

When changing an offer of the railway transport or electrification of the track the change in costs for the train operation happen due to the realization of the project. Costs for operation of trains were mostly assessed based on the multiplication of the cost rate related to train hours and train hours in the past. Currently the “Methodology of the assessment of costs for the operation entering the CBA of railway infrastructure projects” is valid. This methodology defines costs for the train operation with greater precision and costs are close to the reality. Thus, determined costs take into account not only train hours, but also train kilometres. Costs include not only the time of the train operation, but also the distance. For the calculation, the specific rates and rates determined especially for the project are used. These rates include costs for the utilization of the specific train unit, its utilization in time, track characteristics etc. Differences are displayed in the table 2. Results calculated according to the new Departmental Methodology are usually bigger than in the past. Possible savings for the train operation could be bigger as well.

| Passenger transport | Previous methodology €/train hour | Departmental methodology €/train hour | Departmental methodology €/train kilometre |
|---------------------|----------------------------------|--------------------------------------|------------------------------------------|
| Suburban            | 135.04                           | 140.88                               | 0.94                                     |
| Long distance       | 147.63                           | 216.96                               | 0.96                                     |

Benefits from the travel time savings for passengers and goods are calculated as a multiplication of the time value defined by methodological instructions and the time saving expressed in person hours. The way of the calculation of time savings expressed in person hours or tone hours remains the same, however the unit time value is changing (see table 3).
### Table 3. Comparison of the unit price of travel time savings

| Description               | Previous methodology €/passenger hour | Departmental methodology €/passenger hour |
|---------------------------|---------------------------------------|------------------------------------------|
| **Passenger transport**   |                                       |                                          |
| Working time              |                                       |                                          |
| Bus                       | 23.30                                 | 18.77                                    |
| Car, train                | 29.03                                 | 23.40                                    |
| Short commute             |                                       |                                          |
| Bus                       | 8.41                                  | 6.55                                     |
| Car, train                | 11.70                                 | 9.12                                     |
| Long commute              |                                       |                                          |
| Bus                       | 10.81                                 | 8.42                                     |
| Car, train                | 15.02                                 | 11.70                                    |
| Other – short distance    |                                       |                                          |
| Bus                       | 7.04                                  | 5.49                                     |
| Car, train                | 9.81                                  | 7.64                                     |
| Other – long distance     |                                       |                                          |
| Bus                       | 9.05                                  | 7.05                                     |
| Car, train                | 12.57                                 | 9.80                                     |
| **Freight transport**     |                                       |                                          |
| Road                      | 4.19                                  | 3.38                                     |
| Railway                   | 1.71                                  | 1.38                                     |

**Costs for roads and highway operation savings** come out from the effect of the transferred transport. Due to the realization of the railway construction, the part of passengers or goods is transferred from the road to the railway. Savings in the operations costs on roads and operations costs of cars can appear. In the previous methodology, costs were calculated based on the number of transported person or ton kilometres. The Departmental Methodology assesses the costs according to the car kilometres and differs between individual and public transport and consequently between light and heavy freight transport. This could lead to the refinement of results of this effect. Comparison of costs see in the table 4 and 5.

### Table 4. Comparison of costs for roads and highway operation savings

| Operation of cars | Individual €/car kilometre | Bus €/car kilometre | Light freight transport €/car kilometre | Heavy freight transport €/car kilometre |
|-------------------|----------------------------|---------------------|----------------------------------------|----------------------------------------|
| Previous methodology | 0.23                     | 0.81                | 0.34                                   | 1.09                                   |
| Departmental methodology | 0.21745908            | 0.738503507         | 0.351519875                            | 0.843725643                            |

### Table 5. Comparison of costs for the road infrastructure operation

| Maintenance and repairs of road infrastructure | Previous m. | Dep. m. | Previous m. | Dep. m. |
|-----------------------------------------------|-------------|---------|-------------|---------|
| Personal €/1000 person kilometre              | 0.18        | 0.76    | 6.83        | 6.01    |
| Individual €/1000 car kilometre              | 1.9         | 36      | 1           | 9       |
| Bus €/1000 car kilometre                     | 1.22        | 1.41    |             |         |
| Freight €/1000 ton kilometre                 | 154.26      | 1.22    |             |         |
| Light freight transport €/1000 car kilometre |             |         |             |         |
| Heavy freight transport €/1000 car kilometre |             |         |             |         |

In the case of **externalities in the form of decreasing of accidents, noise, air pollution and climate changes**, the saving comes out from the transfer of the transport from the road to the railway. The
railway transport is friendlier from the aspect of production of externalities. Mainly the transfer from the road to the railway brings savings in external costs of transport.

In the frame of the previous methodology, this benefit was valuated as a multiplication of personal kilometres and the cost rate for the variant with project and without project. In the frame of the Departmental Methodology, external benefits are calculated from:

- decrease of accidents calculated according to the demonstrable decrease of fatal accidents, accidents with injuries and accidents with the material damage on solved part of transport infrastructure, or average rates of external costs of accidents,
- decrease of noise calculated according to the noise load of people within the project variant and variant without project, or it is possible to use simplified values of external costs of noise for the specific transport mode,
- decrease of the air pollution calculated according to the amount of pollutants produced by the transport within the project variant and variant without project, the calculation is more detailed and in three steps:
  1. calculation of transport performance in particular segments of transport,
  2. assessment of amount of emitted/saved tons of pollutants and
  3. valuation of pollutants using unit costs per ton

is able to determine the saving or additional load on environment caused by realization of the projects,
- the slowdown of the climate changes calculated according to the amount of produced carbon dioxide and its valuation using unit costs per ton of carbon dioxide.

The new approach defined in the Departmental Methodology is more detailed than aggregated one used in previous methodologies. At the end of the comparison it is necessary to declare that in the case of criterial indexes for the financial and the economic analysis no difference in calculation between previous and present methodologies were detected. The discount rate 5 % and the evaluation period 30 years remain without changes.

4.3 Case study
Quantified differences between the efficiency assessed using the Departmental Methodology and using the previous methodology are presented on the case study of the model project. The intention of the construction is the complete reconstruction of the railway station including the new solution of railroad trucks and reconstruction of related objects. The aim of the construction is the increase of the competitive ability of the railway transport, the increase of the quality of the railway operation and the increase of the comfort and the safety for passengers. This aim will be reached through the increase of the speed (shortening of travel times), modernization of elements of the railway infrastructure and carrying out of new platforms and wheelchair access including subways. Basic input parameters for the financial analysis are costs for construction 62 601 000 € without VAT and investment costs 67 875 000 € without VAT. Results of the financial and economic analysis se in tables 6 and 7.

| Description                        | Previous methodology | Departmental methodology | Difference |
|------------------------------------|----------------------|--------------------------|------------|
| Total incremental operation costs  | 27 090               | 26 939                   | -151       |
| Total investment costs without reserve | -66 075             | -66 075                  | 0          |
| Residual value                     | 1 033                | 1 008                    | -24        |
| FNPV                               | -37 952              | -38 128                  | -175       |
| FRR                                | -9.21%               | -9.48%                   | 0.00       |

The economic analysis also includes the model of person hours and transport performance.
### Table 7. Results of the economic analysis – discounted cash flow (€)

| Description                                      | Previous methodology | Departmental methodology | Difference |
|--------------------------------------------------|----------------------|--------------------------|------------|
| Saving operation costs - railway                 | 24 607 984           | 22 467 754               | -2 140 230 |
| Saving operation costs - road                    | 22 892               | 21 252                   | -1 640     |
| Saving operation costs of trains - railway       | 2 922 666            | 1 936 579                | -986 087   |
| Saving operation costs of cars - road            | 3 112 950            | 2 904 055                | -208 894   |
| Savings of travel time                           | 43 441 462           | 31 766 524               | -11 674 938|
| Savings in externalities                         | 7 317 585            | 3 326 692                | -3 990 893 |
| Other benefits                                   | 230 842              | 230 842                  | 0          |
| Residual value                                   | 8 718 872            | 7 086 361                | -1 632 511 |
| **Total benefits**                               | **60 858 905**       | **52 417 186**           | **-8 441 719** |
| Total investment costs without reserve           |                      |                          |            |
| **Total costs**                                  | **60 858 905**       | **52 417 186**           | **-8 441 719** |
| ENPV                                             | 29 140 749           | 17 322 873               | -12 193 474|
| **ERR**                                          | 9.43%                | 8.24%                    | -1.19%     |
| **BCR**                                          | 1.485                | 1.330                    | -0.155     |

It is evident from calculations of the financial and the economic analysis that re-calculation of the economic evaluation according to the Departmental Methodology leads to the decrease of the financial and economic efficiency of the project – in the case of ENPV the decrease is 22.83% (from table 8).

The table 8 shows impacts of particular changes in variables (change from previous methodology to Departmental Methodology) on the change of ENPV selectively.

### Table 8. Results of the sensitivity analysis – discounted cash flow (€)

| Description                                      | ENPV      | Deviation % |
|--------------------------------------------------|-----------|-------------|
| Project variant – previous methodology           | 29 140 749|             |
| Project variant – Depart. Methodology             | 17 105 961| -22.83%     |
| One-parameter analysis                           |           |             |
| Saving operation costs - railway                 | 27 028 506| -7.25%      |
| Saving operation costs - road                    | 29 139 130| -0.01%      |
| Saving operation costs of trains - railway       | 28 167 557| -3.34%      |
| Saving operation costs of cars - road            | 28 934 586| -0.71%      |
| Savings of travel time                           | 17 618 483| -39.54%     |
| Savings in externalities                         | 25 202 044| -13.52%     |
| Other benefits                                   | 29 140 749| 0.00%       |
| Residual value                                   | 27 529 586| -5.53%      |
| **Total costs**                                  | 37 472 076| +28.59%     |

From the sensitivity analysis, it is evident that the highest difference from the original value in the case of ENPV is caused by travel time savings, which are traditionally very important benefit of transport infrastructure projects, and significantly lower contribution of savings in externalities. The differences report the significant decrease of ENPV values. Other changes in calculations of benefits seem to be marginal. At the same time, it is necessary to state that thanks to the change of the factor of conversion for the investment costs calculation the result of the economic analysis is from this point of view better.
5. Conclusions
The paper is focused on the assessment of the impact of the change in the methodology on the financial and economic evaluation of railway infrastructure projects. The paper maps key areas, where changes caused by the change of methodology appeared. The impact of changes is presented on the case study of the model project of the railway infrastructure realization. From the evaluated case it is evident the decrease of the financial and the economic efficiency mainly in the field of travel time savings, which are perceived as a traditional significant benefit of transport infrastructure project generally. However, it is not possible flatly consider that this decrease would happen in the case of any project. The reason consists in the possibility of the individual calculation of some items, as costs for the train or car operation, or factors of conversion. Within this evaluation the recommended universal values were used. The next factor, which influences the construction efficiency, is new way of the assessment of costs for the maintenance and the recovery of the railway infrastructure. The use of the approach causes changes in values of savings of operational costs of the railway infrastructure. In this evaluation, the costs for the recovery of the railway infrastructure, within the variant without project, were considered from to the similar projects evaluated according to the previous methodology. The previous methodology came out mainly from experiences of the administrator of the infrastructure.

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