Ewa **OŁDAKOWSKA**

EVALUATION OF THE SOCIO-ECONOMIC COST-BENEFIT CATALOGUE IN ASSESSING THE ECONOMIC EFFICIENCY OF ROAD INVESTMENTS

Ewa **Ołdakowska** (ORCID: 0000-0002-5437-2470) – *Bialystok University of Technology*

Correspondence address:
Wiejska Street 45, 15-351 Białystok, Poland
e-mail: e.oldakowska@pb.edu.pl

ABSTRACT: The aim of the article is to present an evaluation of the cost-benefit catalogue of socio-economic taken into account in the economic efficiency analyses of road projects, drawn up on the basis of the guidelines contained in the "Blue Book" (road infrastructure) and in the "Instructions for assessing the economic efficiency of road and bridge projects for national, provincial, district and municipal roads". The results of the economic calculation including the different cost categories: vehicle operation, time of road infrastructure users, road accidents and casualties, related to air pollution emissions, climate change, noise, depend primarily on the algorithms used and the unit costs included.

KEYWORDS: cost-benefit analysis, socio-economic costs and benefits, economic efficiency assessment of road and bridge projects

Introduction

Making decisions connected with road infrastructure investments involves detailed economic assessment of the benefits or disadvantages that can be attributed to its implementation. The development of road infrastructure promotes transport accessibility, which determines the competitiveness of individual regions in the global economy. The spatial, temporal, and economic accessibility is a necessity resulting from the increasing mobility of people and the growing transport of goods. Among other things, developing infrastructure has a positive impact on the "activity" of citizens, increasing the supply of labour (which mitigates the effects of unemployment), improves the safety and comfort of travel, contributes to reducing transport costs including external costs (air pollution, accidents, congestion). Its development, also through the introduction of innovations (e.g. Intelligent Transport Systems), improves the use of infrastructure, saving travel time or reducing vehicle operating costs. Road investments are undertakings belonging to a group of projects, the implementation of which brings primarily socio-economic benefits and not profit in accounting terms.

A basic tool to estimate the results, primarily social welfare, using available data, is cost-benefit analysis (Mouter, 2021; Rosik & Wójcik, 2023). Its popularity results, among other things, from the availability of methodological manuals, the mandatory use in the evaluation of projects co-financed by the European Union or by international organisations (Europan Commision, 2023).

The aim of this article is to present an evaluation of the catalogue of socio-economic costs and benefits in Poland over the last 15 years, taken into account in economic efficiency analyses of road projects, drawn up on the basis of national guidelines. The most up-to-date list of cost/benefit categories is contained in the "Blue Book" (road infrastructure) (Jaspers, 2023), while an earlier list can be found in the "Instructions for assessing the economic efficiency of road and bridge projects for national, provincial, county, and municipal roads" (Instytut Badawczy Dróg I Mostów, 2008, 2008a, 2008b, 2008c), which were quite widely used. However, they have not been updated and are not mandatory for use in current analyses. The impact of changes is best reflected in user and environmental cost values, which are a very important component of cost-benefit analysis.

Economic efficiency and its categories

The aim of this article is to present and compare the catalogue of socio-economic costs and benefits taken into account in the economic efficiency analyses of road projects, drawn up on the basis of the guidelines contained in the "Blue Book" (road infrastructure) and in the "Instructions for assessing the economic efficiency of road and bridge projects for national, provincial, district and municipal roads" (Instytut Badawczy Dróg i Mostów, 2008).

The management sciences define economic efficiency as the relationship between the effect, which is the result of an activity, and the input, understood as the use of the production factor necessary to carry out that activity (Ćwiąkała-Małys & Nowak, 2010; Dowgiałło, 1993; Matwiejczuk, 2000; WielkaEncyklopediaPWN, 2002). In the sciences in economics, efficiency is considered at different "levels" and efficiency is distinguished as:

- megaeconomic (Jaki, 2012), resulting from the creation of economic unions,
- macroeconomic (in relation to the economy as a whole),
- mesoeconomic (including market actors, businesses, households),
- microeconomic (considering market actors, enterprises, households).

In turn, publications in the field of finance divide the efficiency into (Ćwiąkała-Małys & Nowak, 2010; Kochaniak, 2010):

- cost efficiency (the relationship of an entity's costs to the average level of costs that similar organisations generate),
- revenue efficiency (the relationship of the income/revenue of the entity under consideration to the average level of income/revenue of similar organisations),
- efficiency as determined by the profit criterion (the ratio of the profit achieved to the maximum possible profit obtainable under the given conditions),
- financial efficiency (derived from the financial statements).

DOI: 10.34659/eis.2024.90.3.911

This multidimensional approach makes it impossible to establish a single universal performance measure and the evaluation should take into account various aspects and different points of view (Bielski, 2002; Głodzinski, 2014), among which are:

- organisational considerations (results increase as a result of improved individual or group work organisation, including ensuring proper communication and coordination of activities),
- technical considerations (results increase as a result of new, rationalised materials or tools),
- innovative considerations (effects change after product innovation has been developed and implemented),
- financial considerations (results are derived from the organisation's financial activities),
- environmental considerations (effects resulting from environmental activities, e.g. reduction of atmospheric emissions or waste reduction),
- marketing considerations (results are the outcome of marketing activities, e.g. leading to increased brand recognition),
- legal considerations (the results are the result of measures to secure the research facility or to enable additional benefits).

Therefore, different types of performance measures are used, depending on the specific characteristics of the projects and the expectations of the investor.

Economic efficiency of road investments

Road investments are undertakings belonging to a group of projects, the implementation of which brings primarily socio-economic benefits and not profit in accounting terms. The economic analysis of infrastructure investment projects uses various measures to assess economic efficiency with different threshold requirements. The analysis is expected to conclude with an expression, in the form of a single numerical value, denoting the ratio of the benefits generated over the years of operation to the value of the investment incurred. Among the commonly used dynamic methods for the economic evaluation of investment projects, the following indicators stand out: net present value (NPV), internal rate of return (IRR), modified rate of return (MIRR), net present value ratio (NPVR), and benefit-cost ratio (B/C Ratio). In addition to dynamic methods, there are also static methods in the literature, among them there are payback period, simple and accounting rate of return, cost comparison (Wrzosek, 2008).

The correctness of the economic efficiency calculation of investment projects requires the observance of certain principles (Kozubek, 2012; Rogowski, 2004; Szablewski et al., 2008):

- the principle of additiveness, whereby the costs and benefits taken into account in assessing economic efficiency are derived from the period of the investment,
- the principle of unambiguity, according to which the application of the same method of assessing economic efficiency by two different people should give the same result,
- the principle of comprehensiveness, taking into account all costs incurred and effects achieved in connection with the investment project,
- the principle of objectivity, i.e. treating numerical data objectively, and not subjective,
- the principle of disregarding so-called "sunken costs" (costs incurred before the decision was taken with the exception of outlays which are recoverable in the event of cancellation of the investment),
- the principle of clarifying the life of a project,
- the principle of comparability, which is based on the principle of time-dependence, even if the costs and benefits of an investment diverge widely over the analysis period, when balancing the inputs and outputs of the investment in question,
- the principle of incrementality, meaning the necessity of taking into account in the effectiveness account the increments of inputs and outputs which will occur as a result of the investment project (in connection with the transition from the initial state to the target state of the investment), rather than their nominal values,
- the principle of consistency, which draws attention to the consistent use of fixed elements in the economic efficiency account, such as the type of currency, inflation and the discount rate,
- the principle of disclosure and fair description of all assumptions and simplifications made,

DOI: 10.34659/eis.2024.90.3.911

- the principle of universality, indicating the selection for analysis of such methods and procedures, methods, and procedures by means of which different types of projects (e.g. new and modernisation) can be assessed with minor adjustments.

A detailed methodology for conducting economic analyses of road investments is included in the "Blue Book" (Jaspers, 2023) dedicated to Polish projects implemented in the road infrastructure sector and in the "Manuals for assessing the economic efficiency of road and bridge projects for national, provincial, county and municipal roads" (Instytut Badawczy Dróg i Mostów, 2008, 2008a, 2008b, 2008c). Those manuals have been created in order to standardise the approach to cost-benefit analysis and to ensure comparability of assumptions and methodology. They use standard indicators for evaluating projects: internal rate of return and net present value. The principle applies that values are not discounted in the first year of the analysis. The assessment also establishes the ratio of the project's discounted benefits to its discounted costs (the monetised balance of the project's benefits and costs for society and the environment). The discount rate reflects society's view of how future benefits and costs should be valued, relative to current benefits and costs. The value of the social discount rate is usually lower (at most equal) than the value of the financial discount rate under the given economic conditions. It is related to the difference in individual and social perceptions of the value of time, and consequently future monetary values, as it has been proven that society as a whole is more patient than individuals. In Poland, in the financial perspective 2007-2013, the level of the discount rate set by the European Commission for the procedures for the distribution of EU funds was 5.5%. In 2015, after internal discussions and consultations with the JASPERS initiative and the largest beneficiaries in the transport sector, the social discount rate for Polish transport projects was set at 4.5% (CUPT, 2016). In contrast, currently, according to the current recommendations of the European Commission, if the financial discount rate is 4%, the value of the social discount rate should be 3% (Jaspers, 2023).

The project analysis is carried out using the differential method (composite method, i.e. the transport forecast and calculations for the no-investment (W0) and investment (WI) variants are prepared separately). Then, the results obtained for W0 are subtracted from the WI results – the difference describes the project. The correct performance of the differential analysis depends on a carefully defined non-investment variant (W0), i.e. a project that will not be implemented, but will be the reference against which all investment variants will be compared. In case of a greenfield investment from scratch, W0 is effectively the "do nothing" option. It therefore assumes the maintenance of the existing technical condition of the infrastructure, means of transport or transport equipment, and their ability to provide services, both in terms of standard and volume (throughput, capacity, capacity). Operating costs and replacement expenditures are set at a level that allows this condition to be maintained. As assets age, maintenance costs may increase over time in real terms.

Method and procedures for evaluating the economic efficiency of road investments

The most popular method in Poland for assessing the impact of non-commercial projects on the economy is the Cost-Benefit Analysis method. This analysis should include all possible costs and benefits, including the quantified non-monetary effects, generated by the project during the implementation and exploitation period, both for the investor and other beneficiaries. At the same time, this assessment should provide an answer to the question of whether the project is in the public interest and is intended to allow a choice between two or more mutually exclusive investments. In order to achieve comparability, the analysis shall express all costs and benefits of the associated with the project are expressed in monetary terms. Although the idea of the analysis is simple, its correct use for assessing efficiency poses many difficulties and problems, because of the way in which costs and benefits are valued, especially those that do not have a market value.

Cost-benefit analysis is also a mandatory element of documentation for projects applying for EU funding. In the current budget perspective (2021-2027), the analysis methodology is regulated and formalised (Jaspers, 2023). The primary (Polish) sources of the detailed methodology are the "Blue Books" covering the railway sector, the public transport sector, and road infrastructure. The Road

DOI: 10.34659/eis.2024.90.3.911

Blue Book (Jaspers, 2023) provides guidance based on well-chosen best practices and is in line with the in line with the European Commission's key guidance. Its content and structure is as follows:

- stage I – identification of options and preparation of input data,
- stage II – socio-economic analysis,
- stage III – financial analysis,
- stage IV – assessment of project risks.

The calculation of economic efficiency based upon the "Instructions ..." (Instytut Badawczy Dróg i Mostów, 2008, 2008a, 2008b, 2008c) is:

- traffic measurement and calculation of the average daily traffic (SDR),
- forecast of average daily traffic,
- travel speed,
- road costs,
- vehicle operating costs,
- costs of time in passenger transport,
- costs of time in freight transport,
- costs of road accidents,
- costs of toxic exhaust emissions,
- costs of users and environment.

The sensitivity analysis is the supplementary stage in the assessment of road and bridge investments. Investment costs are included in the study, and the degree of detail depends directly on the location of the investment. In case of investments out of the cities administrative limits the investment costs increase by 15% is analysed, and in case of investments in the city areas it is required to analyse the investment costs increase by 25% (Instytut Badawczy Dróg i Mostów, 2008, 2008a, 2008b, 2008c).

Catalogue of socio-economic costs and benefits in economic efficiency assessments of road investments

The analysis of costs and advantages is the useful and versatile assessment of the investment project and determination if a gives project "deserves" to be realized from the social point of view. For this purpose, social benefits/savings are valued and environmental benefits/savings (the environment sustains life on earth, provides resources and services), which in the case of road infrastructure projects, according to the Blue Book (Jaspers, 2023) and best practice, are calculated based on the following main cost categories:

1) operation of vehicles,
2) time of road infrastructure users,
3) road accidents and victims,
4) connected with emissions of air pollutants,
5) climate changes,
6) noise.

In recent years, work has also been underway to expand the catalogue of external costs, for example, to include the costs of biodiversity loss or loss of ecosystems.

Operating costs of vehicles

Operating costs of vehicles are all costs incurred by users travelling on the road network included in the analysis, among which there are:

- fuel consumption costs: dependent on road course in terrain and traffic conditions (speed),
- other costs: road technical condition affecting wear of vehicles, including oil costs, tyre wear, inspections, and depreciation.

These costs are estimated by two main vehicle categories: light vehicles (LV) and heavy vehicles (HGV), unless the traffic forecast results are presented in a more detailed breakdown (e.g. into five categories). For vehicle operating costs, it has been assumed that the current road vehicle fleet, by type of fuel used, consists mainly of petrol and diesel vehicles, not including electric vehicles. However, it should be noted that such fleet structure is constantly evolving and an increase in the share of

DOI: 10.34659/eis.2024.90.3.911

electric vehicles is to be expected (following climate change mitigation policies), which should imply taking into account the evolution of vehicle operating costs. Currently, some countries include electric and autonomous vehicles in their operating costs by introducing provisional values for the necessary parameters used in cost-benefit analyses (NSW, 2022; Lutsey& Nicholas, 2019).

Currently, the calculation follows formula (1) (Jaspers, 2023):

$$K_e = \sum_{j=1}^{2} k_{ej}\left(V_{pdr\,j}, T, S\right) \cdot 365 \cdot W_j^{km}, \quad (1)$$

When using the algorithm according to the “Instruction ...” (InstytutBadawczyDrógiMostów, 2008, 2008a, 2008b, 2008c), the operating costs have been determined based on formula (2):

$$K_e = L \cdot \sum_{j=1}^{5} k_{ej}\left(V_{pdr\,j}, T, S\right) \cdot 365 \cdot SDR_j, \quad (2)$$

where:
K_e – annual vehicle operating costs [PLN],
J – number of vehicle categories,
k_{ej} – unit operating costs for vehicles of category “j” as a function of road class/travel speed V_{pdrj}, terrain line T, and technical condition of road pavement S, in [PLN/veh.-km],
speed V_{pdrj} – transport work for vehicles of category “j” depending on the length of the road section in vehicle-kilometres/day, $W_j^{km} = L \times SDR_j$ [PLN/veh. km],
SDR_J – annual average daily motor vehicle traffic [vehicle/day],
L – length of analysed road section [km].

Time costs of road infrastructure users

The time costs of road infrastructure users are the total time costs of people making journeys on the analysed road or street network. Due to different motivations for travel, travellers are divided into different categories (Jaspers, 2023):
- travelling for business purposes,
- travelling daily between home–work–home (known as commuting),
- travelling for other motivations (e.g. tourism, shopping, etc.).

In the calculation (sectional calculation of transport work), the passenger vehicle load should be taken for each of the different motivations, based on studies and measurements carried out in the road corridor in question. In case of urban projects, the passenger vehicle fill should be taken according to data for the respective city. If no such data is available, the filling values presented in the “Blue Book” (Jaspers, 2023) should be used in the calculation. The time costs of road infrastructure users should be determined separately for each year of analysis, for the two variants as the product of 365, the transport work for the individual vehicle/branch categories and users, the vehicle fill rate, the share of a given motivation in vehicle user journeys, unit time costs.

If the basis for the calculation of time costs of road infrastructure users is the “Instructions ...” (Instytut Badawczy Dróg i Mostów, 2008, 2008a, 2008b, 2008c) then these costs will be calculated separately into time costs in passenger traffic and time costs in freight traffic. In both cases they are determined on the basis of labour costs as defined by the Central Statistical Office and consist of time costs for: business trips and non-work trips. The value of the time consumed is mainly influenced by the speed of the vehicle and the length of the route it takes.

The time costs of road infrastructure users (Koopmans & Mouter, 2020; Wardman et al., 2016) captured in cost-benefit analyses carried out in other countries (26 countries, 389 studies, and more than 3 100 valuations) show very wide variation depending on the range of variables adopted. In addition to the usual time spent in the vehicle, the review studies also considered waiting time, service interval, time of searching for a parking space, time of changing the departure time, time spent in traffic jams, early and late schedule delays, average lateness and standard deviation of travel time or travel in crowded or inconvenient conditions (Victoria Transport Policy Institute, 2023; Waka Kotahi NZ Transport Agency, 2024). It has been found that valuations vary depending on the type of time, GDP, distance, destination, mode of transport, value for money, and a number of other factors related to the estimate.

DOI: 10.34659/eis.2024.90.3.911

Costs of road accidents

Costs of road accidents are the costs borne by all vehicle users as a result of traffic incidents on the roads under study, as well as on those where there will be a change in accident rates resulting from the implementation of the project under study.

The accident costs in each option include (3):

- killed in road accidents,
- slightly injured in road accidents,
- seriously injured in road accidents,
- material damages (incurred in accidents involving injuries and/or casualties).

$$K_w = \sum_{j=1}^{n} [(k_{zt} \cdot a_{zt}) + (k_{rt} \cdot a_{rt}) + (k_{crt} \cdot a_{crt}) + (k_{mt} \cdot a_{mt})], \quad (3)$$

when:
K_w – costs of road accidents, injuries and fatalities incurred over the wholeanalysis period [PLN],
k_{zt} – unit costs of fatalities in the year [PLN],
k_{rt} – unit costs of slightly injured in the year [PLN],
k_{crt} – unit costs of seriously injured in the year [PLN],
k_{mt} – unit cost of material losses in the yea [PLN],
a_{zt} – number of fatalities in the year,
a_{rt} – number of slightly injured in the year,
a_{crt} – number of seriously injured in the year,
a_{mt} – number of traffic accidents with material damage in the year,
t – number of the year of the analysis period (being n=25).

The costs of road accidents determined on the basis of the "Instructions ..." (Instytut Badawczy Dróg i Mostów, 2008, 2008a, 2008b, 2008c) are calculated on the basis of the theoretical or recorded and predicted number of accidents on the analysed road section, calculated by means of appropriate conversion factors, taking into account the different traffic conditions based on formula (4):

$$K_{in} = L \cdot w_{wa} \cdot k_{in} \cdot 365 \cdot \sum_{j=1}^{5} \left(\frac{SDR_j}{1\,000\,000}\right), \quad (4)$$

where:
K_{in} – annual costs of road accidents [PLN],
k_{in} – unit costs of road accidents [PLN/accident],
w_{wa} – accident risk indicators depending on road and traffic conditions a[no. of accidents/1,000,000 veh. km],
SDR_j – average daily traffic volume of vehicles of group j [veh./dobę],
L – length of analysed road section [km].

In European countries, in order to compare monetary valuations of road safety, their main costs have been defined: medical costs, production loss costs, human costs (intangible cost of pain, grief, loss of quality of life, and years of life lost), material damage in the form of damage to vehicles and infrastructure, administrative costs: costs related to the police who intervene in road accidents, fire services, insurance and legal costs, other costs (funeral costs, costs related to traffic jams, and inaccessibility of vehicles) (Wijnen et al., 2019; Daniels et al., 2019). The impact of indirect benefits, resulting from countermeasures (fewer accidents), on road safety has also been considered (Byaruhanga & Evdorides, 2024).

Costs of air pollution

Costs of air pollution represent the costs of environmental nuisance in the surroundings of the road under study; according to the "Blue Book" (Jaspers, 2023), these are the total costs generated by all vehicles travelling on the roads under study/assessment. These costs are related to the environmental impact of transport, primarily in terms of:

- negative impact on human health (mainly cardiovascular and respiratory diseases),
- negative impact on agricultural crops leading to reduced yields or crop losses,

DOI: 10.34659/eis.2024.90.3.911

- material damage (including damage to buildings and facilities),
- environmental damage, including negative impacts on biodiversity and ecosystems.

The calculation of air pollution costs is based on the unit economic costs of air pollution included in Appendix A of the "Blue Book" (Jaspers, 2023). These costs are directly related to the operation of vehicles (mainly fuel-powered) and depend on their types, the condition of the road, its longitudinal gradient and its location (urban or suburban road). The unit economic costs of air pollution are indexed, and the calculations take into account the individual vehicle categories, separately for each option and each year of the economic analysis, in accordance with the traffic forecasts for all categories of economic impact. The calculations are carried out according to formula (5):

$$K_z = 365 \cdot \sum_{j=1}^{2} k_{sj}\,(T, S) \cdot W_j^{km}, \tag{5}$$

where:
K_z – annual costs of air pollutants [PLN],
k_{sj} – unit costs of air pollution by motor vehicles, depending on the terrain line T, and technical condition of the pavement S [PLN/veh. km].

The costs of emission of toxic exhaust components representing the costs of environmental nuisance in the surroundings of a municipal, district, or provincial road are calculated using formula (6):

$$K_s = L \cdot \sum_{j=1}^{5} k_{sj}\left(V_{pdr\,j}, T, S\right) \cdot 365 \cdot SDR_j, \tag{6}$$

where:
K_s – annual costs of emission of toxic exhaust components [PLN],
k_{sj} – unit costs of emission of toxic exhaust components by motor vehicles of group j depending on the speed of travel $V_{pdr\,j}$, terrain line T, and technical condition of the road surface S [PLN/km],
SDR_j – average daily traffic volume of vehicles of group j [veh./day],
L – length of analysed road section [km].

For foreign economic assessments, the treatment of a serious health risk such as air pollution varies depending on key variables, including the discount rate, emission model, or target pollution type. There are also studies that use the method of transferring previously estimated benefits to own calculations (Åström, 2023; Wang et al., 2024).

Climate change costs

Climate change is a global phenomenon, which makes it less important to identify the specific location where harmful gases are emitted and more important to estimate their quantity and clarify the consequences caused by the impact of greenhouse gas (GHG) emissions into the atmosphere. According to the "Blue Book" (Jaspers, 2023), these are the total costs generated by all users travelling on the transport networks under study. The costs of climate change (expressed as CO_2 equivalent) consist of the total CO_2 equivalent emissions multiplied by the unit cost.

The proposed methodology consists of assessing the impact of GHG emissions from road infrastructure projects, resulting mainly from the operational phase of the project (vehicle traffic on the different networks). According to the indicated methodology, GHG emissions other than carbon dioxide CO_2 (i.e. methane CH_4 and nitrous oxide N_2O) are not taken into account as their impact is treated as negligible. In contrast, CO_2 is considered as:

- absolute emissions: the total emissions produced by the project in a typical year of operation,
- relative emissions: given in terms of the incremental (increase/decrease) difference in emissions between the investment and non-investment scenario described in the analysis in a typical year of operation.

In the calculations, the CO_2 costs are the result of multiplying the annual relative emissions of the project by the unit costs. For traffic, the methodology for calculating GHG emissions costs is based on estimating the consequences of the operational phase of the project for internal combustion engine vehicles (LV and HGV) and electric vehicles (LV only). For internal combustion engine vehicles, direct emissions associated with the operation phase are considered, while for electric vehicles, indirect greenhouse gas emissions associated with the associated with the generation and supply of energy to operate electric vehicles (i.e. the grid factor). The annual relative emissions depend on the emissions produced by the users of the various vehicles (and means of transport) on the network, which must be multiplied by the corresponding transport work. Therefore, emission factors depend on the vehicles (and means of transport) of the users, in terms of fuel/energy consumption. For road vehicles, fuel consumption depends primarily on speed, vehicle category, as well as road surface condition and geometry. Climate change costs should be determined separately for each year of analysis, for each option using notation (7):

$$K_{zk} = 365 \cdot \sum_{j=1}^{2} k_{zk,j} \left(Vpdr, j, T, S\right) \cdot W_j^{km,} \tag{7}$$

where:
K_{zk} – annual climate changes costs [PLN],
$k_{zk,j}$ – unit costs of the climate changes by motor vehicles of group j depending on the speed of travel , terrain line T, and technical condition of the road surface S [PLN/. km].

The cost-benefit analyses of climate change have received considerable criticism in the foreign literature, mainly due to controversial discounting choices, as well as large uncertainties in climate vulnerability and climate damages (Ekholm, 2018). However, the harmonised methodology, in line with the carbon footprint calculation methodology of the European Investment Bank, used to assess potential projects makes the European “approach” in this aspect similar (European Commission, 2022).

Noise costs

Noise is a phenomenon that damages both the environment and the and human functioning. It is defined as unpleasant and unwanted sounds which frequencies and intensities are acute to the surroundings. Due to the density of roads and streets distribution, the road noise is particularly troublesome in urbanised areas. The road noise consists of sounds at varying levels.

Calculation of the cost of the impact of excessive noise should be carried out for all projects located in urban areas or for areas of a high population density of potentially exposed people and where such impacts are considered significant. The “Blue Book” presents two calculation methods.

(A) The first method is based upon “final noise impact costs”.

These are unit costs that vary according to traffic, local conditions (urban/urban area), and time of day. The economic noise costs are calculated by vehicle category, separately for each variant and each year of the economic analysis, according to the traffic analysis, using formula (8). The noise costs for the road vehicle category are related to vehicles with internal combustion engines. It is assumed that noise impacts associated with electric vehicles can be ignored (electric vehicles are a noise source, but for simplicity it is assumed that this will be omitted from the analyses until relevant data is available in the literature).

$$K_h = 365 \cdot \sum_{j=1}^{2} k_{h,j} \left(Z\right) \cdot W_j^{km}, \tag{8}$$

where:
K_h – annual noise costs of motor vehicles [PLN],
$K_{zk,j}$ – unit noise costs by motor vehicle category of group j in area Z (urban/non-urban) [PLN/veh. km],
W_j^{km} – transport work for vehicles of category “j” depending on the length of the road section in vehicle-kilometres/day, $W_j^{km} = L \times SDR_j$ [PLN/veh. km].

(B) The second method, a two-stage approach, is dependent on average noise costs.

As a first step, the number of people exposed to above-normal road noise, by vehicle group,are determined (for all options). Estimates can be made based on noise maps (if available) and the corresponding isophones for the different ranges 55÷59 dB(A), 60÷64 dB(A), 65÷69 dB(A), 70÷74 dB(A) and above 75 dB(A). For areas below 55 dB(A), no negative effects are assumed. Once the number of people exposed to each noise level has been determined, a factor is applied to calculate the number of people actually affected by the noise problem. The total costs are then determined by multiplying the number of people exposed to above-normal noise by the corresponding unit costs. This calculation is done based on acoustic maps (if available) for the forecast of the first year after putting the project into operation. For the reference period, projected demographic changes and available forecasts or maps of future noise impacts should be taken into account. For years for which no data are available, the linear interpolation should be used.

A comparison of domestic and foreign approaches reveals that the economic quantification of the costs and benefits of noise impacts depends primarily on cost factors and is done using heterogeneous monetisation techniques. Different countries have set a variety of noise “prices”, and there are some that have not set any unit costs for roads, making it impossible to include them in the analyses (CEDR, 2017; Victoria Transport Policy Institute, 2022).

Comparison of socio-economic costs and benefits using a linear road project as an example

In order to compare the socio-economic costs and benefits determined using the procedures contained in the “Blue Book” (Jaspers, 2023) and the “Instructions ...” (Instytut Badawczy Dróg i Mostów, 2008, 2008a, 2008b, 2008c), data for the investment task of reconstructing a national road have been used (the necessary technical data are presented in Table 1). Moreover, the following assumptions were made:

- reference period – 25 years (for the road projects; since the construction beginning, in this case years 2015-2040),
- year consists of 365 days.

Table 1. Technical data of the national road under consideration

No.	SPECIFICATION	UNIT	W0	WI
1	ROAD	-	NATIONAL	
2	SEGMENT LENGTH	km	21.50	
3	TERRAIN TYPE	-	ROLLING TERRAIN	
4	ROAD TYPE	-	COUNTRY ROAD	
5	ROAD CLASS	-	S	
6	NUMBER OF ROADWAYS	pcs.	1	2
7	NUMBER OF ROADWAY LANES	pcs.	2	2
8	ROADWAY WIDTH	m	7.00	7.00 emergency lane 2.50
9	SHOULDER WIDTH	m	1.50	0.75
10	AVERAGE ALLOWABLE SPEED	km/h	90	120
11	PAVEMENT TECHNICAL CONDITION ACC. TO SOSN (Pavement Condition Assessment System)		C	A
12	BUS BAYS		yes	yes
13	TRAFFIC CHARACTER		COMMERCIAL	
14	INVESTMENT START YEAR	year	-	2015
15	INVESTMENT END YEAR	year	-	2018
16	INVESTMENT NET COST	PLN	-	476 177 042
17	TRAFFIC CATEGORY	KR	6	6
18	BRIDGE OBJECTS	CONDITION	4	5

DOI: 10.34659/eis.2024.90.3.911

In an effort to determine the costs and benefits, the recommended forms have been developed to determine the costs and benefits, upon the basis of which the values presented in Tables 2 and 3 were estimated. The input data adopted for the calculations and analysis, i.e. the calculation period, the cost of the investment, the type and technical and geometric parameters of the road, the technical condition of the road surface and the land line, were identical for both calculation algorithms.

Table 2. Summary of users and environmental costs [thousands of PLN]

Operational costs		Costs of time in passenger transport		Costs of time in freight transport		Costs of road accidents		Costs of toxic exhaust emissions	
WO	WI	WO	WI	WO	WI	WO	WI	WO	WI
1	2	3	4	5	6	7	8	9	10
10 375 397	10 279 442	3 390 409	2 149 345	1 682 441	1 267 394	2 098 646	556 500	1 831 765	1 763 699
53.54%	64.18%	17.50%	13.42%	8.68%	7.91%	10.83%	3.47%	9.45%	11.01%
TOTAL WO = 19 378 664									
TOTAL WI = 16 016 379									

Source: authors' work based on Instytut Badawczy Dróg i Mostów (2008c).

Table 3. Summary of users and environmental costs [thousands of PLN]

Operational costs		Time costs ofroad infrastructure users		Time costs of road accidents		Costs of air pollution		Climate change costs		Noise costs	
WO	WI	WO	WI	WO	WI	WO	WI	WO	WI	WO	WI
1	2	3	4	5	6	7	8	9	10	11	12
6 062 750	5 903 123	8 434 517	5 794 730	437 310	244 095	2 661 303	2 345 415	680 598	615 357	4 538	4 538
33.16%	39.60%	46.14%	38.87%	2.39%	1.64%	14.56%	15.73%	3.72%	4.13%	0.02%	0.03%
TOTAL WO = 18 281 017											
TOTAL WI = 14 907 266											

Source: authors' work based on Blue Book (2023).

The analysis of the data in Tables 2 and 3 makes it possible to observe differences in the values of individual user and environmental costs depending on the depending on the procedure used:

1) The socio-economic costs comprise five cost categories in the "Instruction ..." (operation, user time in passenger and freight transport, road accidents, emissions of toxic exhaust components) and six cost categories in the "Blue Book" (operation, user time, road accidents, air pollution, climate change, noise). This means that the calculation formulas for climate change costs and noise costs only appear in the "Blue Book". It is important in terms of the latest climate policies and targets and in eradicating threats that cause hard-to-quantify damage to human wellbeing. Taken together, these costs account for approximately 4% of all user and environmental costs in both the investment and non-investment variants. A slightly different structure of other costs is also observed, the dominant ones being operating costs and road users' time costs. While in case of the estimation according to the "Manual ..." the operating costs were predominant, in the calculations based on the "Blue Book" the costs of road infrastructure users stand out.
2) Vehicle operating costs according to the Blue Book are determined for two categories of vehicles (light vehicles (LV) and heavy vehicles (HGV)) and account for more than 30% and almost 40% of total user and environmental costs in the no-investment and investment variants, respectively. However, according to the "Manual ...", they were defined for five categories of vehicles: cars, vans, lorries without trailers, lorries with trailers, and buses. In this case, they account for more than half of the cost structure. The differences in the values obtained result from using different vehi-

DOI: 10.34659/eis.2024.90.3.911

cle categories and different unit operating costs, which are an essential element of the two algorithms used, containing analogous factors.

3) The time costs of road infrastructure users, determined upon the basis of the "Instructions ...", have been calculated by dividing the time costs in passenger transport and the time costs in freight transport, while in the "Blue Book" they are the total time costs of persons making trips (characterised by different motivations) on the analysed road or street network.As for theoperating costs, the two calculation formulas are almost identical. The difference in the final results is determined by the different values of the unit time costs taken. They are significant enough to make the cost of users' time in the first case more than 20% in total of all user and environmental costs, and twice as much in the second one.
4) The accident costs estimated using the algorithms included in the "Instruction ..." are costs that are independent of the severity or nature of the accident, but connected to a risk index that takes into account the characteristics of the road and the average daily traffic of a group of vehicles.On the other hand, the values determined upon the basis of the data included in the "Blue Book" are the costs: material damage, injuries, serious injuries, and deaths. This valuation of the unit statistical cost of a human life has practical justification not only in economic efficiency assessments but also for road traffic safety improvement measures.
5) The air pollution costs and their unit values depend on the terrain line T and the technical condition of the pavement S (Jaspers, 2023) or are determined by travel speeds , the terrain line T, and the technical condition of the pavement S (InstytutBadawczyDrógiMostów, 2008, 2008a, 2008b, 2008c). In both cases, they account for approx 10-15% of all user and environmental costs.

The diverse approach to determining user and environmental costs has been confirmed by an analysis of 45 project documentations made available by the General Directorate for National Roads and Motorways concerning the construction of bypasses and expressways in Poland. The studies included 28 bypass construction projects, 1 motorway extension project, and 17 expressway construction documentations. In 40 cases, the economic assessment has been carried out using the "Blue Book", while in 4 cases the costs of users and the environment have been estimated upon the basis of the procedure included in the "Instructions...". In one of the "examples" provided, the guidelines provided in the "Instructions..." have been used, the information from the "Blue Book" have beenused as auxiliary only.

Summary

The selection of a priority investment task or the right project option is a complex issue. It is aided by the results of various analyses and evaluations of greater or lesser complexity. A tool that makes it possible to assess the economic efficiency of road investments is the method of analysis of the costs incurred and the benefits obtained, especially social benefits.

The socio-economic costs and benefits of investment road projects are currently estimated in categories including: vehicle operating costs, road infrastructure user time costs, road accident and casualty costs, emissions costs, climate change costs, and the impact costs of excessive noise. Changes in the "Polish" catalogue of socio-economic costs and benefits over the years have meant that the costs of climate change and the costs of the impact of excessive noise are included in current economic analyses, which is important in terms of the latest climate policies and targets and the fight against threats that cause hard-to-quantify losses in human well-being. Because of this, the structure of users and the environment costs has also changed, although operating costs and road users' time costs are still dominant. In a further stage of the work, the Authors plan to attempt to establish a relationship between cost levels and their structure.

The calculation procedures presented in the "Blue Book" and the earlier "Instructions ..." are characterised, in the case of vehicle operating costs and the time costs of road infrastructure users, by an analogous scheme of calculations. The differences in the final results are the result of using non-uniform unit costs. A definitely different and more appropriate approach is noted with regard to the estimation of accident costs, which is characterised by greater detail in the "Blue Book".

The comparison carried out allows us to conclude that the current catalogue of socio-economic costs and benefits addresses the relevant risks and facilitates the implementation of current European Union policies.

DOI: 10.34659/eis.2024.90.3.911

Acknowledgements

The article has been prepared in range of work no. WZ/WB-IIL/7/2023 and has been financed from the resources of The Ministry of Science and Higher Education for science.

References

Åström, S. (2023). Perspectives on using cost-benefit analysis to set environmental targets – a compilation and discussion of arguments informed by the process leading to the 2016 EU air pollution emission targets. Environmental Impact Assessment Review, 98, 106941. https://doi.org/10.1016/j.eiar.2022.106941

Bielski, M. (2002). *Podstawy teorii organizacji i zarządzania*. Warszawa: Wydawnictwo C.H. Beck. (in Polish).

Byaruhanga, C. B., &Evdorides, H. (2024). The impact of indirect benefits (reduced travel time, fuel use and emissions) in cost benefit analysis of road safety countermeasures. Traffic Injury Prevention, 25(3), 434-439. https://doi.org/10.1080/15389588.2024.2322665

CEDR. (2017). *State of the Art in Managing Road Traffic Noise: summary report.*https://www.cedr.eu/download/Publications/2017/CEDR2017-03-State-of-the-art-in-managing-road-traffic-noise.pdf

CUPT. (2016). *Analiza kosztów i korzyści projektów transportowych projektów transportowych współfinansowanych ze środków współfinansowanych ze środków Unii Europejskiej: Vademecum beneficjenta.*https://www.cupt.gov.pl/strefa-beneficjenta/wdrazanie-projektow/analiza-kosztow-i-korzysci/metodyka-analizy-kosztow-i-korzysci/vademecum-beneficjenta/ (in Polish).

Ćwiąkała-Małys, A., & Nowak, W. (2010). *Wybrane metody pomiaru efektywności podmiotu gospodarczego.* Wrocław: Wydawnictwo Uniwersytetu Wrocławskiego. (in Polish).

Daniels, S., Martensen, H., Schoeters, A., Van den Berghe, W., Papadimitriou, E., Ziakopoulos, A., Kaiser, S., & Perez, O. M. (2019). A systematic cost-benefit analysis of 29 road safety measures. Accident Analysis & Prevention, 133, 105292. https://doi.org/10.1016/j.aap.2019.105292

Dowgiałło, Z. (1993). *Słownik ekonomiczny dla przedsiębiorcy w warunkach rynkowych.*Szczecin: Wydawnictwo „Znicz". (in Polish).

Ekholm, T. (2018). Climatic Cost-benefit Analysis Under Uncertainty and Learning on Climate Sensitivity and Damages. Ecological Economics, 154, 99-106. https://doi.org/10.1016/j.ecolecon.2018.07.024

European Commission. (2022). *Harmonised system-wide cost-benefit analysis for candidate carbon-dioxide transport networks and storage projects.*https://energy.ec.europa.eu/system/files/2022-10/20220907_DRAFT_METHODOLOGY_CBA_CO2%20final.pdf

European Commission. (2023). *Economic appraisal vademecum 2021-2027.* https://doi.org/10.2776/182302

Głodziński, E. (2014). Efektywność ekonomiczna – dylematy definiowania i pomiaru. Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie, 73, 155-167. http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-9f73d895-2539-49fc-a3f4-5ccb3d7be1be (in Polish).

Instytut Badawczy Dróg i Mostów. (2008). *Instrukcja oceny efektywności ekonomicznej przedsięwzięć drogowych i mostowych dla dróg gminnych.* Warszawa: Instytut Badawczy Dróg i Mostów. (in Polish).

Instytut Badawczy Dróg i Mostów. (2008a). *Instrukcja oceny efektywności ekonomicznej przedsięwzięć drogowych i mostowych dla dróg powiatowych.* Warszawa: Instytut Badawczy Dróg i Mostów. (in Polish).

Instytut Badawczy Dróg i Mostów. (2008b). *Instrukcja oceny efektywności ekonomicznej przedsięwzięć drogowych i mostowych dla dróg wojewódzkich*. Warszawa: Instytut Badawczy Dróg i Most**ów.** (in Polish).

Instytut Badawczy Dróg i Mostów. (2008c). *Instrukcja oceny efektywności ekonomicznej przedsięwzięć drogowych i mostowych – weryfikacja metody badań zgodnie z zaleceniami UE oraz aktualizacja cen jednostkowych na poziomie 2007 r.* Warszawa: Instytut Badawczy Dróg i Mostów (in Polish).

Jaki, A. (2012). *Mechanizmy procesu zarządzania wartością przedsiębiorstwa.* Kraków: Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie. (in Polish).

Jaspers. (2023). *Niebieska Księga. Infrastruktura drogowa. Inicjatywa Jaspers.*https://www.cupt.gov.pl/strefa-beneficjenta/wdrazanie-projektow/analiza-kosztow-i-korzysci/metodyka-analizy-kosztow-i-korzysci/niebieskie-ksiegi-2021-2027/ (in Polish).

Kochaniak, K. (2010). *Efektywność finansowa banków giełdowych.* Warszawa: Wydawnictwo Naukowe PWN. (in Polish).

Koopmans, C., & Mouter, N. (2020). Chapter One – Cost-benefit analysis. Advances in Transport Policy and Planning, 6, 1-42. https://doi.org/10.1016/bs.atpp.2020.07.005

Kozubek, P. R. (2012). *Efektywność inwestycji infrastrukturalnych w transporcie kolejowym analiza i ocena.* Kielce: Wydawnictwo Politechniki Świętokrzyskiej. (in Polish).

Lutsey, N. P., & Nicholas, M. (2019). Update on electric vehicle costs in the United States through 2030. International Council on Clean Transportation, 06, 1-12. https://doi.org/10.13140/RG.2.2.25390.56646

Matwiejczuk, R. (2000). Efektywność – próba interpretacji. Przegląd Organizacji, 11, 27-31. https://doi.org/10.33141/po.2000.11.05 (in Polish).

Minister Funduszy i Polityki Regionalnej. (2023). *Wytyczne dotyczące zagadnień związanych z przygotowaniem projektów inwestycyjnych, w tym hybrydowych na lata 2021-2027.*https://www.funduszeeuropejskie.gov.pl/strony/o-funduszach/fundusze-na-lata-2021-2027/prawo-i-dokumenty/wytyczne/wytyczne-dotyczace-zagadnien-zwiazanych-z-przygotowaniem-projektow-inwestycyjnych-w-tym-hybrydowych-na-lata-2021-2027 (in Polish).

Mouter, N. (2021). Standard Transport Appraisal Methods. Advances in Transport Policy and Planning, 7, 1-7. https://doi.org/10.1016/bs.atpp.2021.02.001

NSW. (2022). *Transport for NSW Technical Note on Calculating Road Vehicle Operating Costs. Version* 2.0. https://www.transport.nsw.gov.au/system/files/media/documents/2022/TfNSW%20CBA%20Technical%20Note%20Vehicle%20Operating%20Cost%202022.pdf

Rogowski, W. (2004). *Rachunek efektywności przedsięwzięć inwestycyjnych.*Kraków: OficynaEkonomiczna. (in Polish).

Rosik, P., & Wójcik, J. (2023). Transport Infrastructure and Regional Development: A Survey of Literature on Wider Economic and Spatial Impacts. *Sustainability,15*(1), 548. https://doi.org/10.3390/su15010548

Szablewski, A., Pniewski, K., & Bartoszewicz, B. (2008). *Value Based Management. Koncepcje, narzędzia, przykłady.* Warszawa: Poltext. (in Polish).

Victoria Transport Policy Institute. (2022). *Transportation Cost and Benefit Analysis II – Noise Costs.* www.vtpi.org/tca/tca0511.pdf

Victoria Transport Policy Institute. (2023). *Transportation Cost and Benefit Analysis II – Travel Time Costs.* www.vtpi.org/tca/tca0502.pdf

Waka Kotahi NZ Transport Agency. (2024). *Monetised benefits and costs manual.* https://www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual

Wang, S., Song, R., Xu, Z., Chen, M., Luca, G., Di Tanna, Gl., Downey, L., Jan, S., & Si, L. (2024). The costs, health and economic impact of air pollution control strategies: a systematic review. Global Health Research and Policy, 9(1), 30.https://doi.org/10.1186/s41256-024-00373-y

Wardman, M., Chintakayala, V. P. K, & De Jong, G. C. (2016). Values of travel time in Europe: Review and meta-analysis. Transportation Research Part A: Policy and Practice, 94, 93-111. https://doi.org/10.1016/j.tra.2016.08.019

Wielka Encyklopedia PWN. Tom 8. (2002). Warszawa: Wydawnictwo Naukowe PWN. (in Polish).

Wijnen, W., Weijermars, W., Schoeters, A., Van den Berghe, W., Bauer, R., Carnis, L., Elvik, R., & Martensen, H. (2019). An analysis of official road crash cost estimates in European countries. Safety Science, 113, 318-327. https://doi.org/10.1016/j.ssci.2018.12.004

Wrzosek, S. (2008). *Ocena efektywności inwestycji.* Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu. (in Polish).

Ewa OŁDAKOWSKA

EWALUACJA KATALOGU KOSZTÓW I KORZYŚCI SPOŁECZNO-EKONOMICZNYCH W OCENACH EFEKTYWNOŚCI EKONOMICZNEJ INWESTYCJI DROGOWYCH

STRESZCZENIE: Celem artykułu jest przedstawienie ewaluacji katalogu kosztów i korzyści społeczno-ekonomicznych uwzględnianych w analizach ekonomicznej efektywności projektów drogowych, sporządzanych na podstawie wytycznych zawartych w „Niebieskiej Księdze" (infrastruktura drogowa) i w „Instrukcjach oceny efektywności ekonomicznej przedsięwzięć drogowych i mostowych dla dróg krajowych, wojewódzkich, powiatowych i gminnych". Wyniki rachunku ekonomicznego ujmującego różne kategorie kosztów: eksploatacji pojazdów, czasu użytkowników infrastruktury drogowej, wypadków drogowych i ofiar, związanych z emisją zanieczyszczeń powietrza, zmian klimatu, hałasu, uzależnione są przede wszystkim od zastosowanych algorytmów i ujętych w nich kosztów jednostkowych.

SŁOWA KLUCZOWE: analiza kosztów i korzyści, koszty i korzyści społeczno–ekonomiczne, ocena efektywności ekonomicznej przedsięwzięć drogowych i mostowych

DOI: 10.34659/eis.2024.90.3.911