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The problem of using the cost-benefit analysis in making decisions about electromobility development in urban public transport in Poland

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Abstract

Motivation: Polish Act on Electromobility and Alternative Fuels obliges 83 cities to prepare every three years cost-benefit analysis (CBAs) using zero-emission buses (ZEBs) in urban public transport. First-time obligated institutions prepared them in 2018. The organisations indicated in the Act on Electromobility, and Alternative Fuels had experience using this tool, e.g. applying for EU co-financing of investment projects. However, the analysis of the selected documents shows significant differences in the approach to developing CBAs.

Aim: The aim of the study is to identify the most critical problems related to the use of CBA as a decision-making tool for the implementation of investments involving the performance of ZEBs in urban public transport. The study identifies the main advantages and limitations of the instrument. It also proposes introducing requirements by the legislator, which could increase the comparability of CBA results and thus reduce the uncertainty of decisions.

Results: Using CBA as a decision-making tool requires maintaining an appropriate methodological regime. It involves the identification of alternative projects that allow the realisation of the objectives set by the decision-maker. Its essence is to identify the undertaking that will allow achieving the best results from the organisation's point of view and from the social, environmental, and economic perspective. The research indicates that the lack of explicit guidelines from the legislator concerning the methodology of CBA

preparation for the needs of ZEB implementation hinders comparability of the obtained results and reduces uncertainty of decisions made on their basis.

Keywords: cost-benefit analysis; decision making; zero-emission buses; urban public transport
JEL: A11; D61; R41

1. Introduction

Reducing greenhouse gas emissions and breaking the economy's dependence on fossil fuels is critical global and European Union objective. This goal is to be achieved through the implementation of a sustainable development policy. In its communication COM/2019/640 *The European green deal*, the European Commission indicates that by 2050 the European economy should achieve zero net greenhouse gas emissions. Transport is marked as one of the most emitting sectors of the EU economy, next to energy and industry. It is estimated that in 2018. 21.2% of greenhouse gas emissions within the European Union were generated by the transport sector (EEA, 2021).

Meeting ambitious decarbonisation targets for the European economy requires implementing appropriate programmes to support the development of low-emission transport systems and the involvement of public funds. In Poland, the flagship programme for developing more ecological transport has become the *Electromobility development plan* adopted by the Council of Ministers in 2017. This document indicates the expected directions of activities supporting the development of zero-emission means of transport, among other things, to create zero-emission urban mobility.

The implementation of zero-emission transport systems in urban areas is most often identified with the replacement of buses fleets or the development of battery trolleybuses. Such an impression can be given by analysing Article 36 of the Act of 11 January 2018 on electromobility and alternative fuels, in which the legislator refers only to car transport systems. Indeed, the document omits critical zero-emission mobility systems in the form of rail transport.

Replacing the bus fleet with zero-emission vehicles requires the commitment of significant financial resources, not only for the purchase of ZEBs but also for constructing an appropriate feeder infrastructure. Investments in urban mobility development are made with public funds. That requires a proper level of transparency in the decision-making process and, therefore, the use of appropriate techniques and methods for project evaluation.

The Act on Electromobility and Alternative Fuels requires the most prominent local government units acting as public transport authorities (PTAs) to prepare cost-benefit analyses (CBAs) of the implementation of zero-emission buses (ZEBs) regularly. In November 2020 Supreme Audit Office (SAO, 2020), in the information on the results of the audit *Support for electromobility development*, indicated that 94% of local government units complied with this obligation. The legislator has not issued guidelines concerning obligatory assumptions and the expected standard of document preparation. Therefore, the method-

ology of preparing CBAs is not uniform and may raise doubts as to the reliability of its practice. It should be noted that only 11% of entities surveyed by SAO demonstrated the economic effectiveness of the implementation of ZEBs at the level and within the time assumed by the legislator.

The paper aims to identify the most significant problems related to applying CBAs in the decision-making process in the implementation of zero-emission vehicles in urban public transport in Poland. This objective will be achieved by identifying the main advantages and disadvantages based on literature research. The essential areas of uncertainty in the CBAs prepared by local government units, which may affect their results and thus the decisions made on their basis, will also be identified.

The study is qualitative in nature. It uses a desk research technique and is based on secondary data analysis. The theoretical context of the study has been presented in the synthetic literature review. The methodological part describes the applied research procedure and the method of research sample selection. The study results show the findings of the comparative analysis of CBAs prepared by the six most prominent PTAs in Poland. The fundamental differences in the applied methodology of preparing CBAs have been identified and the areas in which the examined entities adopted common assumptions.

2. Literature review

Transport investments are undertaking requiring high initial outlays and generating high operating costs. Most often, these investments are financed from public funds. Making investment decisions in transport is therefore subject to discussion and social evaluation, especially in the context of effective management of public funds as well as their social and environmental impact. That means that decisions made by public finance entities require a strong evidence base and objective rationale (Damart & Roy, 2009, p. 201). This condition can be met by using appropriate methods and techniques in the decision-making process to evaluate investment projects.

The procedure for evaluating transportation projects follows three steps: identification of alternative projects, estimation of costs and benefits of their implementation, and selection of the implementation option (Lee & Kim, 2017, pp. 44–52). Single-criteria or multi-criteria methods are used to evaluate individual projects as well as transport policies (Beria et al., 2012, pp. 137–152). Single-criteria methods are most often based on a monetary approach and include cost-benefit analysis (CBA) or cost-effectiveness analysis (CEA) (Browne & Ryan, 2011, pp. 226–233). Multi-criteria analysis (MCA) allows evaluating projects considering various criteria, often not measurable in monetary form. The MCA are applied to evaluate transport projects include analytical hierarchy process (AHP), analytic network process (ANP), multiple-criteria decision analysis (MCDA), REGIME or methods from the ELECTRE family (Beria et al., 2012, pp. 137–152, Henke et al., 2020a, pp. 1–27; Wolff et al., 2018).

Due to the different limitations of single and multi-criteria methods, scientists are looking for methods that combine the advantages of both approaches and eliminate their disadvantages is conducted, which include the COSIMA model (Ambrasaite et al., 2011, pp. 944–953; Barfod & Salling, 2015, pp. 1–15) and SUMINI (Thomopoulos & Grant-Muller, 2013, pp. 315–345). The most used methods for evaluating transportation projects are multiple-criteria decision analysis (MCDA) and cost-benefit analysis (CBA) (Annema et al., 2015, pp. 788–797). The principles of applying both tools, assessing their objectivity, and their applicability are important research problems.

To the best of our knowledge, research on the area addressed in this article has focused primarily on:

- comparison of project evaluation methods (Annema et al., 2015; Barfod & Salling, 2015; Beria et al.; Browne & Ryan, 2011; Henke et al., 2020a; 2020b);
- setting the conditions for the use of tools in the transport domain (Browne & Ryan, 2011; Eliasson & Lundberg, 2012; Grunicke et al., 2020; Jones et al., 2014);
- the competence and skills of public sector decision-makers with a critical role in transport policymaking in their ability to use the tools mentioned above in decision-making (Annema et al., 2015; Barfod & Salling, 2015; Damart & Roy, 2009; Vigren & Ljungberg, 2018);
- identifying the advantages and limitations of both tools (Ambrasaite et al., 2011; Andersson et al., 2018; Balbontin et al., 2020; Beria et al., 2012; Browne & Ryan, 2011; Damart & Roy, 2009; Grunicke et al., 2020; Jones et al., 2014; Mackie et al.,2014; Vigren & Ljungberg, 2018);
- identification of critical areas affecting the level of uncertainty in their results (Ambrasaite et al., 2011; Asplund & Eliasson, 2016; Beria et al., 2012; Beukers et al., 2012; Flyvbjerg, 2009; Flyvbjerg et al., 2002; Lee & Kim, 2017; Mackie et al., 2014);
- the usefulness of the methods considering the uncertainty aspect of their results (Asplund & Eliasson, 2016, pp. 195–205);
- the search for a comprehensive method of evaluating transportation projects that consider the strengths and address the weaknesses of dominant techniques (Ambrasaite et al., 2011; Barfod & Salling, 2015; Pagliara, 2021; Vickerman, 2017; Thomopoulos & Grant-Muller, 2013).

In assessing transport projects, it is necessary to consider the forecast of demand for transport, the estimation of time, safety, environmental and economic impacts. Both MCDA and CBA are tools that consider the direct costs and revenues resulting from the implementation of a project by a specific entity and consider its impact on the external environment (Annema et al., 2015, pp. 788–789). The external benefits obtained may justify the implementation of unprofitable ventures from the perspective of financial analysis (Beria et al., 2012, pp. 137–151; Browne & Ryan, 2011, pp. 226–233).

CBA is the most utilised method for evaluating significant transport investments and transport policies. It is used in the European Union countries, mainly to evaluate investments implemented through Community intervention. National governments and international institutions applied it as a tool for the efficient allocation of scarce resources. In the member states of the European Union, its application is formally regulated, and the existing methodology regulates the basic principles of its use for the evaluation of large investment projects implemented with the support of Community funds (Andersson et al., 2018; Jones et al., 2014, pp. 400–409). It is based on an integrated assessment of projects and a comparison with alternative options. The CBA methodology utilizes both for the evaluation of individual projects and their groups. It allows ranking projects that are likely to achieve the best results from the community's point of view (Eliasson & Lundberg, 2012, p. 46).

A distinctive feature of CBA is the assessment of external impacts through the analysis of monetised economic effects. This analysis is based on multi-year projections of expected external impacts over an assumed reference period, subject to a discounting procedure (Beria et al., 2012, pp. 139–140). At the same time, CBA is a complex method that requires a multifaceted assessment of projects not only from a financial and economic point of view but also from an organisational, legal, and technical perspective. Because in CBA, the basis for project evaluation is the obtained economic efficiency indicators, it is considered the most transparent, structured, and rational tool (Vigren & Ljungberg, 2018, p. 560).

The biggest challenge associated with the use of CBA as a decision support tool is the reliable identification of potential external benefits and costs, how to value them and the reliability of forecasts that form the basis for assessing the effectiveness of the project. In the case of transport projects, the effects resulting from, e.g. modal shifts between modes and branches of transport, the impact on emissions of greenhouse gases and environmentally harmful substances, noise emissions, time savings, the availability of certain services and markets, and the safety of traffic participants may be of crucial importance for project evaluation. The implementation of transport investments can affect the attractiveness of space, competitiveness, and economic development (Mackie et al., 2014, pp. 3–18). Often the effects in these areas are synergistic, i.e. they occur because of the parallel impact of other investment projects implemented in each area, making it challenging to identify the real impact of the analysed projects. Therefore, the CBA requires the use of clear procedures for impact identification and the establishment of standardised methods for its valuation (Damart & Roy, 2009, pp. 202–203).

Many scientists criticise the CBA method. The main limitations of its application include the possibility of subjective selection of analysed externalities and the way of their pricing. Discussions arise mainly over the valuation of intangible effects. Scholars also have doubts about the reliability of discounting monetised but uncertain economic effects in the long term (Jones et al., 2014,

pp. 400–409). Researchers point to areas of CBA that may be subject to manipulation, significantly affecting the outcome of the analysis, which may influence some reluctance of decision-makers to base their decisions, often political in nature, on this tool (Andersson et al., 2018, pp. 120–146). Studies indicate that up to 9 out of 10 transport infrastructure investment projects may have underestimated implementation costs, significantly affecting CBA performance and decision-making (Flyvbjerg et al., 2002, pp. 279–295). It is also noted that CBA is made at a very late stage of project involvement, basically as a tool for final assessment of the effectiveness of the action without the possibility of adjusting the strategy. Given that it is used as a kind of "decoy for decision-makers" with the power to trigger financial interventions for project implementation, it is likely that project promoters may steer the results of the analyses through overly optimistic cost-benefit valuation (Beukers et al., 2012, pp. 68–78; Flyvbjerg et al., 2002, pp. 344–367; Henke et al., 2020a, pp. 1–27).

A rather curious observation is that CBA often makes it difficult for policymakers to interpret its findings (Barfod, 2018, pp. 1052–1066). Policymakers often approach it with distrust and do not always make decisions based on its findings. The CBA procedure appears to decision-makers as unintuitive and opaque, especially when it comes to selecting alternative implementation scenarios or the valuation of non-market benefits. It is a problematic method for constructive policy discourse — its results are essentially zero-sum in nature and not subject to public discussion (Damart & Roy, 2009, pp. 200–212). Therefore, it is pointed out that CBA is not a decision rule, but only a decision support tool, indicating the ventures decisions can lead to maximising net socio-economic benefits due to applying public financial intervention (Grunicke et al., 2020). However, the literature emphasises that CBA can be treated as a filter for decisions, eliminating investments with clearly negative economic and environmental impacts (Eliasson & Lundberg, 2012, pp. 29–48).

Despite its justified criticism, CBA is a method with significant cognitive value. It should be treated as an attempt to systematise decision-making processes. Considering the significant limitations of this tool, researchers are looking for new, better-adjusted tools for transport project evaluation. It is postulated that CBA can be combined with MCDA to provide objective data and forecasts (Barfod & Salling, 2015, pp. 1–15; Henke et al., 2020a, pp. 1–27). Researchers refer, for example, to the composite modelling evaluation method (COSIMA), allowing to include in the decision-making process both monetizable benefits and costs as well as effects objectively impossible to express in monetary values (Ambrasaite et al., 2011, pp. 944–953; Barfod & Salling, 2015, pp. 1–15). Others propose the inclusion of broader impacts in project appraisal frameworks in the spirit of the SUMINI method, allowing social and spatial equity indicators to be included in the analysis (Pagliara, 2021). The need to contain synergistic, network and agglomeration effects in CBA is pointed out (Beukers et al., 2012, pp. 68–78; Jones et al., 2014). It is postulated that classical CBA should be extended to include tools that allow considering the preferences of in-

dividual and altruistic users and non-users of the implemented investments, e.g. by including the public in determining alternatives (Balbontin et al., 2020, pp. 2981–3030). The most significant advantages and limitations of using CBA are identified in Table 1.

3. Methods

The identification of the research problem is the result of observations on preparing and using the CBAs by the PTAs in Poland to implement the zero-emission transport systems, including ZEBs. Experience shows that this method is used by authorities responsible for the organization of public transport in urban areas in two cases:

- as an element of application documentation, related to the application for investment project financing from external sources (e.g. European Union funds);
- in connection with the need to implement the obligations arising from Article 37 of the Act of 11 January 2018 on electromobility and alternative fuels.

CBA is a mandatory document developed by entities applying for support for transport projects from European funds. The binding methodology for preparing CBA in this regard is presented in the *Guide to cost-benefit analysis of investment projects economic appraisal tool for cohesion policy 2014–2020*. Based on that document, the Centre for EU Transport Projects was developed in 2016 *Vademecum beneficiary: analysis of costs and benefits of transport projects co-financed from European Union funds*, which provides detailed guidelines for the development of CBAs forming the basis for applying for support from the Operation Program Infrastructure & Environment 2014–2020. Given that Polish PTA's and public transport operators successfully apply for support for their investment projects, it can be assumed that this tool is known, which increases the likelihood of applying correct procedures for its preparation. Consequently, it can be assumed that the CBA plays a critical role in the decision-making process for implementing electromobility in urban public transport in Poland.

The survey covered six PTA's, i.e., Warsaw, Municipal Transportation Association of the Upper Silesian Industrial region (KZK GOP; as of 2019 its rights and obligations were taken over by the Metropolis GZM), Cracow, Poznan, Lodz, and Wroclaw. The study assumed that the most prominent PTAs are entities serving voivodeship cities. Data analysis showed that 18 voivodship cities are served by almost 60% of the bus fleet used in Poland in urban public transport. The entities that had the most significant number of buses in 2018 were selected for analysis. The studied entities represent less than 10% of the PTAs obliged by the legislator to develop a CBA to implement ZEBs. In comparison, the fleet constitutes about 40% of the buses used in Poland (Table 2).

In the first stage of the study, a literature review was conducted. Articles indexed in the Scopus database were analyzed. The bibliographic analysis indicates that representatives of various scientific disciplines have analyzed de-

cision-making in transport investments since the 1970s. However, it should be noted that this topic has increased its importance in last decade (Chart 1). The bibliographic analysis, allowing for the determination of critical publications, was performed by establishing a database of documents meeting the following search criteria: article title, abstract, keywords — "decision making" and "investments", and "transport". The adopted search strategy made it possible to identify 853 documents potentially related to the examined subject matter. In the next step, the database of documents subject to analysis was limited to the research areas Social Science, Business, Management and Accounting, Decision Science and Economics, Econometrics and Finance with the status "final". In a further stage, the search was limited to articles and chapters in monographs available in the "open access" mode. The results were then filtered by limiting the search to materials containing keywords directly related to decision making, venture evaluation methods, and issues. As a result of reviewing the abstracts of the identified source materials, a list of articles potentially directly relevant to the issue under study was determined. Particular attention was paid to research results on the application of CBA as a tool to support policy and investment decisions related to the development of transportation systems. In the next phase, the source documents of the articles selected in the earlier stage were reviewed. The database of second layer documents was limited to articles published in open access indexed in the Scopus database.

Further, searches for the phrases "cost-benefit analysis" and "transport" were applied to the second layer documents. The abstracts of the selected papers were analyzed for potential relevance to the use of CBA as a decision support tool for transport investments, which allowed us to select the final database of articles, the full texts of which were analyzed. The sources applied in the study were those directly related to the researched problem.

The second part of the study consisted of a review and comparative analysis of the CBAs for implementing ZEBs in urban public transport produced by or for the studied entities. The following documents were examined:

- cost-benefit analysis of using zero-emission buses to provide public transport services in the Cracow agglomeration (City of Cracow, 2018);
- cost-benefit analysis of the use of zero-emission buses and other means of transport in the provision of public transport services in Lodz (City of Lodz, 2018);
- cost-benefit analysis of the use of zero-emission buses in the provision of pub-lic transport services in Poznan (City of Poznan, 2018);
- cost-benefit analysis of the use, in the provision of public transport services, of zero-emission buses and other means of transport using only engines that do not result in emissions of greenhouse gases or other substances covered by the greenhouse gas management system (City of Warsaw, 2018);
- cost-benefit analysis of the use of zero-emission buses and other means of transport using only engines that do not result in emissions of greenhouse

gases or other substances in the operation of public transport services (City of Wroclaw, 2018);
– cost-benefit analysis of using electric vehicles in urban transport organized by KZK GOP (ZTM Katowice, 2019).

The analysis focused primarily on identifying common and divergent assumptions in their preparation. During the analysis, it was noted that while financial analyses were prepared using similar methodologies, in the case of economic analysis, the differences can significantly affect the reliability of the results. Therefore, the study is concentrated only on identifying the most significant areas that may generate uncertainty in the results of economic analysis.

The research has been carried out using the desk research technique. The study was carried out based on existing data, which gives rise to certain limitations of the research results. The intention of the surveyed entities concerning the choice of methodology for preparing CBA has not been analyzed. Neither was the knowledge and perception of this tool by persons responsible for making investment decisions of PTAs examined, which could explain the approach to the preparation of the document, the choice of assumptions, e.g. in the identification of alternative decision-making options.

4. Results

The Polish legislator, for unknown reasons, refrained from issuing guidelines for the development of CBAs for the implementation of ZEBs in urban public transport. Thus, it left to the obliged entities a wide field of interpretation and great freedom in identifying external impacts, applicable doctrines for their monetization, principles for discounting economic flows, or indication of the applicable reference period, which has a significant impact on the residual value of the analyzed projects. The principles of differentiation of decision-making options were also not indicated, which may have a significant impact on the reliability of the assessment of the economic effectiveness of investment projects.

Most of the surveyed entities declare that the documentation was prepared based on the guidelines used in the case of preparing CBAs for applications for transport projects co-financing from EU funds. These entities refer to the application of the regime defined, among others, in the following studies:
– Guidelines on issues related to the preparation of investment projects, including income generating projects and hybrid projects for 2014–2020 developed by the Ministry of Infrastructure and Development;
– Blue Book — Public transport sector in cities, agglomerations, regions — document produced by the JASPERS Initiative (2015);
– Best practices for cost-benefit analysis of transport projects co-financed from EU funds — published by the Centre for EU Transport Projects (2014);
– The cost-benefit analysis of transport projects co-financed from EU funds is the beneficiary handbook published by the Centre for EU Transport Projects (2016).

However, the study identified some differences in assessing the economic efficiency of ZEBs deployment (Table 3).

All analyzed entities assumed the same discount rate in financial analysis (4%). Most of them also applied the same discount rate in economic analysis (4.5%) — the exception was the cities of Lodz and Cracow, which used 4% discount rate in their economic analysis. In most cases, a comparable reference period (15 years) was applied. However, the city of Wroclaw considered a significantly more extended period, as much as 25 years. In the compared documentation, a difference concerning the adopted base year of the analysis is noticeable — while Warsaw adopted 2017 as the base year, Cracow — 2018, the remaining entities considered 2019 as the base year.

The PTAs adopted different approaches to identifying alternative decision-making options. The Warsaw analyzed three scenarios (stagnation and two development scenarios) for which two variants were identified (non-investment and investment). The analysis of the development scenarios indicates that the non-investment scenarios refer to a situation in which the bus fleet will be successively replaced by zero-emission vehicles by the assumptions of the fight for clean air strategy adopted in 2017. On this basis, it was assumed that the City of Warsaw would replace 80 vehicles powered by conventional fuels with ZEBs vehicles each year. The investment options include an increase in the rate of replacement of the bus fleet with electric vehicles. In the investment development variants, the City of Warsaw envisions replacing the diesel-fueled fleet with hybrid or CNG-fueled vehicles. None of the investment development variants provides the purchase of electric buses above the number provided for in the non-investment variant.

The City of Cracow initially analyzed six alternative investment decision options. These alternatives were differentiated according to the vehicle fueling technology applied (BEV and FCEV), the vehicle charging system (number and type of vehicle charging stations). A preliminary analysis was conducted based on the multi-criteria evaluation method. For further analyses based on the multi-criteria evaluation, two investment variants were selected compared to the base variant.

In the analyses prepared by the remaining entities, one baseline and two alternative variants were identified each. In the case of KZK GOP, the identified alternative variants did not refer in the analysis to the choice of vehicle power supply technology. It was assumed that the provisions of the Act would be implemented through the electric bus system. Investment variants were differentiated in terms of the adopted model of the organization of the public transport management system. The first variant analyzed the model based on the obligation of operators to provide public mass transport services using electric bus fleet and operator charging network by contracting public mass transport services to entities having an appropriate number of electric vehicles. The second option was the assumption that operators could provide public mass transport services using electric buses fleet and the operator's charging network.

In the case of Wroclaw, investment variants, like KZK GOP, were limited to solutions consisting of the implementation of the electric bus system. The analyzed variants were differentiated by adopting different assumptions for the vehicle charging technology (using only the depot system or using a combined strategy based on the depot power supply and fast pantograph chargers).

In addition to the base option, the City of Poznan, in its analysis, identified two alternative investment variants. However, it should be noted that all decision-making alternatives were considered in two versions — for the lines operated by the largest operator and for all lines organized by the City of Poznan. The basis for their differentiation was the choice of the vehicle power supply technology. One of the analyzed variants envisages the implementation of an electric vehicle system and the construction of a power supply system. The second is based on purchasing a hydrogen bus system and the construction of a hydrogen filling station.

A similar scheme of distinguishing analyzed alternatives was adopted in the analysis prepared for Lodz. In the second variant, however, there is no question about implementing the hydrogen bus system but purchasing vehicles powered by CNG.

Most of the papers reviewed assumed the following benefits associated with ZEBs implementation to assess economic efficiency:

- avoidance of air pollution costs resulting from the emission of harmful substances (e.g. PM, nitrogen compounds and sulphury compounds);
- avoidance of climate change costs resulting from CO2 emissions;
- avoidance of noise costs resulting from the operation of buses on public roads.

It should be noted that KZK GOP has not considered the benefits arising from noise reduction. The estimation of benefits resulting from the implementation of ZEBs is based on National Balancing and Emission Management Centre KOBiZE (Poznan, Cracow, Wroclaw, Warsaw, Lodz) or using the emission calculator available on the Centre for EU Transport Projects website (KZK GOP). Monetization, in turn, was performed based on unit cost tables to be used in CBAs of the Centre for EU Transport Projects.

In the documents compared, in most cases, identical principles for preparing the economic analysis were adopted, with capital expenditures corrected by a conversion factor of 0.83 and operating costs by a factor of 0.78. However, in its analysis, the City of Warsaw divided capital expenditures into expenditures related to infrastructure (using a conversion factor of 0.83) and bus fleet (conversion factor of 0.87).

In the analysis carried out for the city of Lodz, the dynamic unit cost method was applied to assess economic efficiency, which is characteristic of CEA and not CBA. It is also surprising that in the case of Wroclaw, the economic efficiency analyses were carried out — the procedure was completed at the stage of estimating the benefits related to reducing greenhouse gas emissions and noise.

However, there was no monetization of the identified effects and no assessment of the economic efficiency of the analyzed options.

In their conclusions, most of the examined entities state that the analysis carried out does not justify the implementation of the ZEBs in urban public transport to the extent indicated by the legislator. In the case of Wroclaw, because the procedure for evaluation of economic effects has not been completed, it should be concluded that the CBA carried out does not indicate the legitimacy of implementing the legislator's assumptions. The only entity that proved the legitimacy of implementing ZEBs within the scope specified in the Act on Electromobility and Alternative Fuels is the Capital City of Warsaw. The tool utilized to assess the economic efficiency of the alternatives in most of the cases studied was the determination of ENPV, ERR and BCR. The analysis carried out for Lodz used the dynamic unit cost method in the assessment of economic efficiency. Interestingly, in the case of Wroclaw, the analytical procedure was terminated when estimating the benefits associated with reducing greenhouse gas emissions and noise emissions. No monetization of the identified effects was carried out, and no assessment was made of the economic efficiency of the analyzed alternatives, which means that this document fails to meet the criteria for preparing a CBA.

5. Conclusion

Despite the high level of structuring of the procedure and an integrated approach to the evaluation of investment projects, the CBAs does not eliminate the uncertainty in the decision-making process. This problem was raised, among others, by Flyvbjerg (2009, pp. 344–367), who proved that the results of CBA depend primarily on the reliability of assumptions made for the analysis. The study indicates that this uncertainty may also be generated by the legislator, who failed to issue clear guidelines on applying this method.

However, it should be noted that despite the lack of instructions most of the entities tried to apply the framework for drawing up analogous studies. The studied PTAs used the procedures applied in connection with applying for EU funds. The compared CBAs identified the areas of impact, adopted similar principles for monetizing impacts, applied similar discount rates for economic flows and correction coefficients for investment expenditures and operating costs. The most significant doubts may be raised by how alternative variants were selected for analysis and the possibility that not all potential benefits generated by the project were considered. The analysis of the prepared CBAs shows that it is possible to apply various criteria for such differentiation, and the selection of these criteria may be based on subjective premises. Allowing for the possibility of using subjective premises undermines the objectivity of the tool examined. Thus, it undermines its role in the decision-making process concerning the implementation of ZEBs. It may also give the impression of steering the results of analyses. The surveyed entities could make a subjective selection of assump-

tions adopted for its preparation. It should be remembered that the legislator obliged the examined entities to achieve an appropriate level of the fleet structure requiring high investment outlays in a relatively short period. At the same time, the legislator has indicated that entities that demonstrate in their CBA that the potential benefits do not cover the costs of fleet replacement will be exempt from the obligation to achieve the assumed indicators of ZEBs.

It should be noted that all analyzed organizations which demonstrated the lack of economic justification for implementing electric vehicles in their systems, directly or indirectly (through operators), are applying to support their projects, aimed at replacement of the bus fleet with, e.g., electric or hydrogen vehicles. PTA's prepare CBAs for the application in which they prove that purchasing ZEBs generate a surplus of benefits over costs, which contradicts the results of the documents analyzed in this study. Such an approach indicates that these documents may have been produced as a reflection of the arbitrary political position of the PTA's management. This approach means that the role of CBAs in creating zero-emission urban transport in Poland may be questioned.

The conducted research does not question the legitimacy of preparing CBAs for the implementation of transport projects. It points to a significant gap in the legislator's approach to developing this type of documentation, consisting of the lack of unambiguous guidelines addressed to entities developing the required analyses. This gap causes decisions on implementing ZEBs in urban transport systems to be treated as subjective and not based on rational premises. The introduction of guidelines and mechanisms for controlling the correctness of the documentation preparation would reduce the level of uncertainty in the results of CBAs.

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Appendix

Table 1.
Advantages and disadvantages of using CBA

Advantages	Disadvantages
– the most common method for evaluating transport projects on a global scale	– narrow approach, not considering effects that cannot be monetised but are strategically important
– rigorous, rational method	– complex, time-consuming, and expensive method, requiring specialist knowledge
– method formally regulated by international institutions financing transport projects and public administrations of many countries	– a method whose reliability depends on the quality of the input data, forecasting models and the level of the discount rate — a high level of uncertainty as to the correctness of the results obtained
– it assumes the possibility of quantifying the effects of the project and its valuation in monetary terms	– the possibility of manipulating the results to promote the chosen solution (underestimating costs, overestimating benefits, not considering competing for alternative projects, ignoring, or underestimating the residual value of the investment)
– considers the impact of time on project valuation by discounting the value of the project and its effects	– only considers the point of view of the project promoter, which may make it difficult to identify alternative projects — does not consider the opinion of the social partners
– theoretically overcomes cognitive, structural and process limitations and decision errors	– allows ex-ante evaluation of projects — its results are usually not verified ex-post
– theoretically allows for an unambiguous assessment of the project — the assessment mechanism based on npv and bcr	– role in decision making is debatable — the procedure is often opaque to decision-makers
– despite numerous limitations, it is a good tool for filtering alternative projects	– assumes the primacy of economic over moral values
– allows to create rankings of undertakings generating the best economic effects	– it is performed at a relatively late stage of project preparation, which makes it difficult to correct a wrongly adopted strategy
	– does not consider the planning context (project as part of a broader strategic plan)

Source: Own preparation.

Table 2.
Identification of the PTA understudy

Voivodship	Public transport bus fleet size in voivodship (31.12.2018)	PTA serving the regional capital in 2018	Bus fleet size in PTAs	Share in the total number of buses in Poland (%)
Masovian	2634	Municipality of Warsaw	1818	15.0
Silesian	1846	Communal Transport Union of the Upper Silesian Industrial Area (KZK GOP)	1047	8.6
Lesser Poland	957	Municipality of Cracow	646	5.3
Greater Poland	950	Municipality of Poznan	488	4.0
Lodz	798	Municipality of Lodz	408	3.4
Lower Silesian	784	Municipality of Wroclaw	404	3.3
West Pomeranian	593	Municipality of Szczecin	284	2.3
Lublin	458	Municipality of Lublin	280	2.3
Podlaskie	358	Municipality of Bialystok	266	2.2
Pomeranian	689	Municipality of Gdansk	264	2.2
Subcarpathian	470	Municipality of Rzeszow	202	1.7
Holy Cross	392	Municipality of Kielce	188	1.5
Kuyavian-Pomeranian	547	Municipality of Bydgoszcz	217	1.8
		Municipality of Torun	158	1.3
Warmian-Masurian	296	Municipality Olsztyn	156	1.3
Opole	172	Municipality of Opole	92	0.8
Lubusz	214	Municipality of Zielona Gora	81	0.7
		Municipality of Gorzow Wielkopolski	81	0.7
total	12158	–	7080	58.2

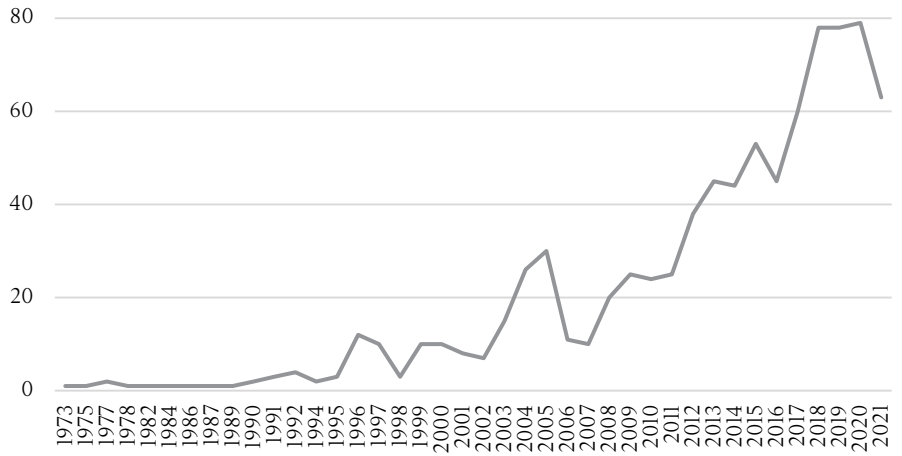
Source: Own preparation based on Statistics Poland (2018) and data uses in CBAs of PTAs.

Table 3.
Identified assumptions for preparing economic analyses within the framework of the examined CBAs

Specification	KZK GOP	Cracow	Lodz	Poznan	Warsaw	Wroclaw
discount rate (%)	4.5	4.0	4.0	4.5	4.5	–
base year	2019	2018	2019	2019	2017	2019
the reference period of economic analysis	15 years	15 years	15 years	15 years	15 years	25 years
the criterion for differentiating decision-making options	organisational and financial model of investment implementation	vehicle power technology model; grid system model	vehicle power technology model	vehicle power technology model	vehicle power technology model; fleet renewal period	vehicle power technology model
analysed ZEB systems	BEV	BEV	BEV; CNG	BEV; FCEV	CNG; Hybrid	BEV
indicators for assessing economic efficiency	ENPV; ERR; B/C	ENPV; ERR; B/C	DGC	ENPV; ERR; B/C	ENPV; ERR; B/C	–

Source: Own preparation.

Chart 1.
Number of publications indexed in database Scopus related to transport investment decision-making



Source: Own preparation based on Scopus database.