

Economic Assessment of Investment in Electric Buses and CNG Buses – A Case Study of a Public Transport Company

Jana Fabianová^{1*}, Jaroslava Janeková²

¹ Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Kosice, Letná 9, Košice, Slovakia

² Faculty of Mechanical Engineering, Technical University of Kosice, Letná 9, Košice, Slovakia

* Corresponding author's e-mail: jana.fabianova@tuke.sk

ABSTRACT

The article deals with green investment focused on urban public transport. This work presents a holistic approach to evaluating investments in electric and CNG buses, i.e., the economic efficiency assessment, including the risk aspect. The investment project is assessed in terms of the source of funding and risk factors affecting the profitability of the project. A non-repayable subsidy from the European Social Fund in the amount of 0%, 25%, 50% and 90% of investment costs is considered. Economic efficiency is assessed in terms of profitability through the financial criterion Net Present Value (NPV) and risk using mean NPV and standard deviation. The result of the evaluation of the variants of the investment project is that the investment project without the support of non-repayable resources is loss-making. With a low level of financial support, it is more economical to procure CNG buses. With a higher level of financial support, investments in electric buses are more profitable, due to lower operating costs.

Keywords: investment decision, e-buses, CNG buses, Monte Carlo simulation.

INTRODUCTION

A European Green Deal aims is to transform the EU to the climate neutral continent. EU's cities, which live over 70% of EU citizens in, offer some of the best opportunities for decarbonization. Sectors as transport, buildings, water, and waste have the greatest potential for high impact decarbonization investments [1]. Green innovation is driven by institutional pressures, and that such innovation can create value in terms of social sustainability [2]. One of the European green deal objectives is Europe's transition to cleaner, greener, and smarter mobility. The main focus is on transport in cities which generate 23% of all transport greenhouse gas (GHG) emissions [3]. Public transport is an essential element of urban transport. So, zero and near-zero emission solutions for urban fleets are prioritized. Nowadays, many research and studies on this topic have been reported in the scientific literature. One of

them, the study by [4], measured exhaust emissions of city buses under real-world stop-and-go traffic conditions. According to the results, hybrid buses can give higher particle number emissions compared to traditional diesel buses. Also, bio-diesel fuel reduced particle number emissions but increased emissions of NO_x which might be due to the higher combustion temperature and oxygen contents of the fuel. Another study conducted by [5] investigated the relationship between the implementation of the smart city concept and the idea of sustainable transport, particularly concerning the reduction of transport generated CO₂ emissions. Specifically, this study estimated potential changes in GHG emissions due to urban road transport in Poland using For Future Inland Transport Systems (ForFITS) model. A new framework to design and compare long term national decarbonization pathways for passenger transportation was introduced by [6]. This framework is based on an iterative method combining

detailed qualitative storylines, full scenario quantification, and standardized dashboard reporting, adapted from the general Deep Decarbonization Pathways (DDP) framework. The impact of hydrogen technology in urban transport was examined by [7], that pointed out how hydrogen vehicles affected the satisfaction of customers, and users through individual projects. Authors of [8] summarised information and insights from zero-emission buses implementations across the United States. Comparative assessment of battery-driven electric buses and fuel-cell electric buses from the view of emission reduction, capital, maintenance and energy costs was presented in [9]. The paper by [10] focused on the interdependent relationship of power generation, transportation and CO₂ emissions. Results indicated that the marginal costs of emission reduction through e-bus transportation were much lower than that through other policy measures. [11] developed an integrated land use–transport–energy model to examine interactions between location choice, land use, transport patterns, energy profiles, and economy when implementing a stringent electric vehicles policy. Research results showed that diffusion of EVs was likely to have significant positive effects on emission reduction in city centres, while economic benefits tended to occur in suburban areas. The paper by [12] outlined issues associated with electric buses' operations. Authors addressed activities that might lead to the transition to more environmentally friendly electric vehicles. The pandemic crisis of COVID-19 has influenced economies and societies around the world. Following this current topic, [13] aimed at developing an urban economic model in the post-COVID world to explore long-term pathways toward deep decarbonization of the transport sector. Likewise, decarbonisation of urban rail is a necessary component of the strategy to minimize anthropogenic emissions. [14] demonstrated the application of the multi-modelling approach comprising key components required for urban rail decarbonisation problems. Different from the above, the idea of decarbonization through global interconnections in an electricity based world was critically discussed by [15]. Substitution of internal combustion engine vehicles with alternative fuel vehicles with zero emissions also has an economic impact. The costs of procuring such vehicles are significantly high, especially in the case of electric buses. In addition to vehicles purchasing, the infrastructure for charging or refuelling is

necessary to build. Together with environmental, various papers dealt with the economic aspects of investment in urban transport decarbonisation. For instance, [16] presented a multi-objective optimization model to find efficient bus fleet combinations taking into account GHG emissions, conventional air pollutant emissions, and costs. Heating and the thermal management of the urban electric buses were the subjects of research in [17]. The article [18] proposed a decision support model for selecting the most appropriate charging strategy for the electric buses in the public transportation. The financial benefits from the use of a dynamic charging system were presented in [19]. As shown in this study, the investment in the traction network allows us to reduce the costs associated with the purchase and replacement of traction batteries, as well as increase the flexibility of the transport system. Similarly, in terms of charging infrastructure, [20] used a mixed-integer linear programming optimization to determine the optimal design of the system in terms of charging infrastructure deployment, battery sizing, and charging schedules. [21] proposed a dynamic model based on the Total Cost of Ownership to seek the suitability of an electric bus concept for Istanbul conditions. The holistic approach presented in [22] evaluated technical feasibility, system cost, energy demand, transportation time, and sustainability-related impacts of various decarbonization strategies. The study by [23] investigated the effect of opportunity charging on the lifecycle costs and carbon dioxide emissions of different urban freight transport operations.

Notably, investment projects are necessarily connected with risk, and decarbonisation investments into urban transport are no exception. Although, research studies examining how risk factors influence the economic efficiency of the investment into e-buses are lacking in the literature. This study aims to investigate the economic efficiency and risks of the investment into electric and CNG busses in a public transport company. The investment project is assessed in terms of funding source and risk factors influencing the project profitability.

CASE STUDY DESCRIPTION

The study deals with the assessment of financial and economic efficiency and risk analysis of an investment project aimed at the renewal of

the vehicle fleet in a company providing public transport using buses and trolleybuses. In 2020, the transport company had 43 buses and 46 trolleybuses at its disposal. Of the 43 buses, 16 are hybrid, 2 are electric buses, the others are diesel buses. The structure and number of buses in years 2016–2020 is recorded in Figure 1.

In 2018, a significant renewal of the bus fleet took place, when 32 new buses were purchased, of which 14 Solaris Urbino 12 IV generation diesel buses, 16 hybrid Iveco Urbanway 12 Hybrid buses and 2 Škoda Perun 26 SH01 Electrobus electric buses. The old buses in amount of 27 were gradually removed from the company’s assets or sold (22 buses in 2019 and 5 buses in 2020). The company plans to complete the renewal of the bus fleet in 2022. It is considering the renewal of 10 buses. Due to the improvement of air quality in the city, the reduction of noise pollution and the improvement of the quality of travel, the choice of buses is oriented towards low-emission vehicles. The

purchase of vehicles is considered in two technical variants:

- variant 1: renewal of 10 after end of lifetime buses for SOR NS 12 electric buses;
- variant 2: renewal of 10 after end of lifetime buses for SOR NBG 18 CNG buses. They are a greener option compared to diesel buses and at the same time cheaper than electric buses.

MATERIAL AND METHODOLOGY

The assessment of the investment project is carried out in two steps. First, the financial and economic efficiency is assessed, then the risks associated with the investment project are analysed. The whole procedure of investment project assessment is presented in Figure 2.

When assessing a project, its alternative solutions are considered (see Figure 3). The individual variants take into account the technical aspect of the project (see Table 1) as well as the method of

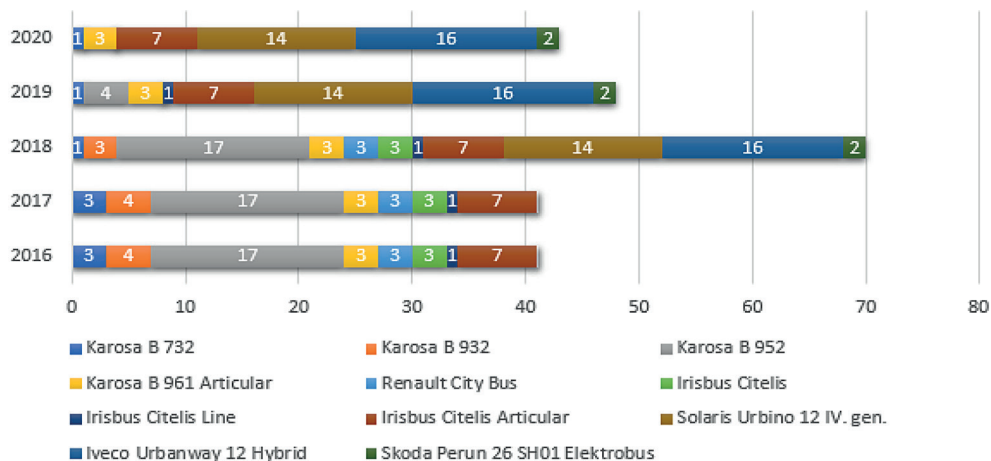


Figure 1 State of buses in years 2016–2020

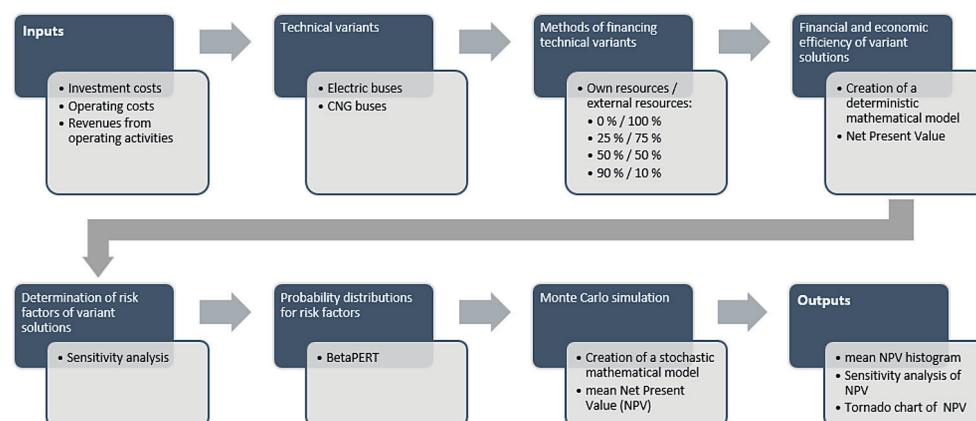


Figure 2. The procedure of investment project assessment

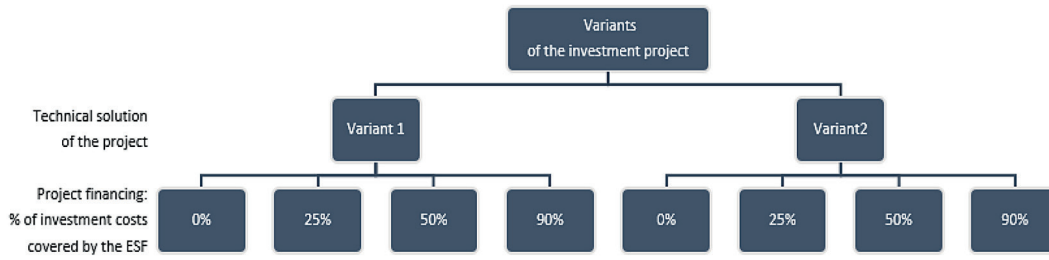


Figure 3. Variants of the investment project

financing the project. Within the financing of the investment project, a subsidy from the European Social Fund (ESF) is being considered, specifically with support in the amount of 0% (own resources), 25%, 50% and 90% of investment costs.

The assessment of the financial and economic efficiency of the investment project is carried out using a mathematical model, which is created in the MS Excel environment for each investment variant. The mathematical model is processed for 10 years, which is the expected lifetime of the investment variants of the project. The evaluation of investment variants is presented for the purposes of this article in terms of profitability, specifically using the Net Present Value (NPV). Its calculation is performed using equations (1) and (2).

$$NPV = \sum_{n=1}^N \frac{CF_n}{(1 + d_r)^n} - IC \quad (1)$$

$$CF_n = EBIDTA_n \times (1 - t_n) + D_n \times d_r \quad (2)$$

where: CF – annual cash flow;
 d_r – discount rate;
 IC – amount of one-off investment costs;
 $EBIDTA$ – earning before interest, tax, depreciation and amortization;
 D – yearly depreciation;
 t – coefficient of income tax rate;
 N – economic lifetime of the investment;
 n – number of years of economic lifetime of the investment.

The input data for the creation of the mathematical model are based on data published in the annual reports of the Transport Company of city of Žilina (Slovakia). The development of the most important cost and revenue items of the company, which may affect the cash flow of the investment project, are recorded in Figures 4–5.

The amount of annual depreciations of individual investment items is determined in accordance with the current Act no. 595/2003 Coll. on income tax:

- CNC buses belong to the 1st depreciation group, they are depreciated over 4 years;
- electric buses, including batteries, belong to the 2nd depreciation group, they are depreciated over 6 years;
- electric charging stations belong to the 3rd depreciation group and are depreciated over 8 years.

Variant 1 investment costs are incurred in the first and sixth year of the project lifetime. In the first year, they consist of the purchase price of 10 electric buses and the costs associated with the construction of two charging stations, which together amount to EUR 6,220,000 (Table 1). After the sixth year of the lifetime of the electric buses, the replacement of 10 batteries is being considered, which leads to an additional one-time investment of EUR 80,000. For variant 2, the investment costs are incurred in the first year alone, amounting to EUR 4,000,000. In the first year of the project’s lifetime, cash income is expected from the sale of decommissioned buses. At an

Table 1. Technical variants of the investment project

Variant	Type	Number	Drive	Investment costs	
				EUR / pcs	EUR
Variant 1	SOR NS 12	10	electric	590,000	5,900,000
	Charging station	10	electric	160,000	320,000
	Battery	2	electric	80,000	800,000
Variant 2	SOR NBG 18	10	CNG	400,000	4,000,000

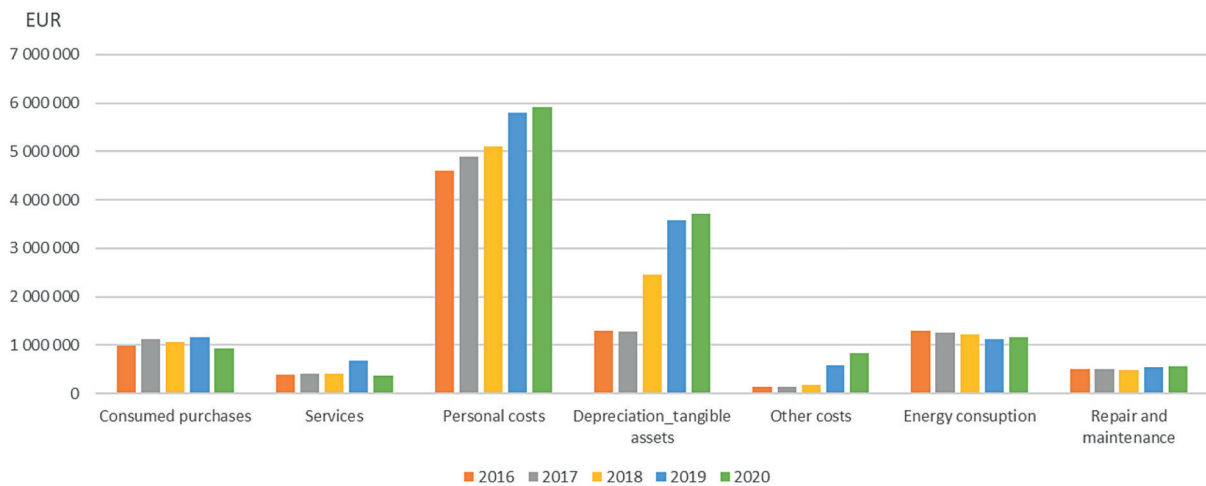


Figure 4. Selected costs of the public transport company

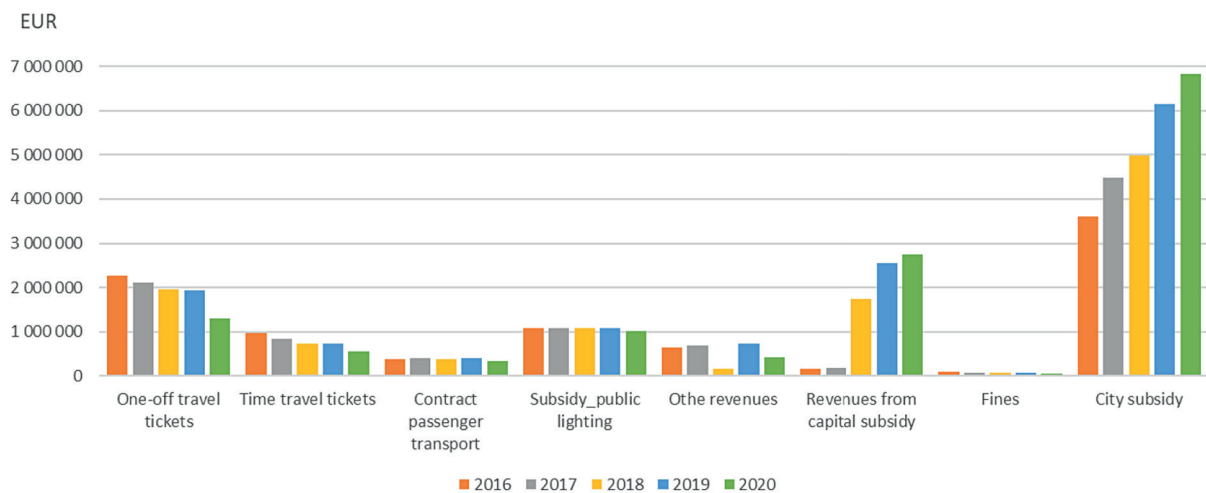


Figure 5. Selected revenues of the public transport company

average price of EUR 5,000 per used vehicle, the total cash income from the sale of vehicles will be EUR 50,000. The cost item consumed purchases, the largest part of which consists of fuels, takes into account cost savings due to the replacement of diesel for electricity or CNG. Due to the fact that the cost of electricity or CNG is much lower than the cost of fuel for diesel buses, these costs in the mathematical model are expressed in terms of savings in electricity using a coefficient of 0.6, in CNG a coefficient of 0.4.

When evaluating investment variants in terms of risk, the mathematical model is adapted to the simulation model in the Crystal Ball program and the use of Monte Carlo simulation. The risk of investment variants is assessed using the financial criterion mean NPV and statistical characteristics – standard deviation. The uncertainty of individual risk factors is determined using probability distribution parameters. Their determination

is based on the development of selected cost and revenue items in the company in years 2016–2020. For all risk factors, the BetaPERT probability distribution is used, which is defined by three parameters: likelist, minimum and maximum (Table 2).

Finally, the individual investment options are compared and the optimal variant in terms of profitability and risk is determined.

It is important to state in the methodology our research does not consider environmental benefits, e.g., CO₂ reduction rates and other environmental impacts caused by the exclusion of diesel vehicles from the bus fleet.

RESULTS

The economic efficiency of the investment is assessed based on the financial indicator Net Present Value. The mathematical model of NPV

Table 2. Probability distributions and statistical parameters of selected risk factors

Risk factor (EUR)	Probability distribution	Minimum	Likelist	Maximum
Consumed purchases	BetaPERT	900,000	930,661	1,010,000
Energy consumption	BetaPERT	1,100,000	1,164,790	1,200,000
Services	BetaPERT	350,000	365,733	400,000
Personal costs	BetaPERT	5,800,000	5,922,563	6,050,000
Repair and maintenance	BetaPERT	540,000	567,187	620,000
One-off travel tickets	BetaPERT	1,200,000	1,309,652	1,400,000
Time travel tickets	BetaPERT	520,000	549,963	570,000
Contract passenger transport	BetaPERT	270,000	299,380	310,000
Fines	BetaPERT	46,000	46,974	48,000
Revenues from capital subsidy	BetaPERT	2,700,000	2,740,531	2,800,000
City subsidy	BetaPERT	6,700,000	6,822,708	7,000,000

calculation for a period of 10 years is created in an Excel spreadsheet. The calculation of the NPV is for different levels of investment financing from the European Social Fund (ESF). Specifically, fund of 0%, 25%, 50%, and 90% of investment costs is envisaged. NPV values calculated for a period of 10 years are presented in Table 3.

The mathematical model for the calculation of NPV is then adapted to the simulation model in the Crystal Ball program, which is a software add-on to Excel. Risk variables were selected by analysing the development of cost and revenue items. Risk variables are those that have the largest share in the value of the company’s output and are key in terms of profit production (e.i. city subsidy, personal costs). Also, risk variables are considered those cost or revenue items that have higher variability in the recent period and are expected to be associated with higher uncertainty (e.i. revenues from transport activity, selling capital subsidy). Cells with variables were supplemented with distribution functions and thus defined as assumptions. BetaPERT distribution is used for all input variables. The parameters of the distribution function (mean, min., max.) are based on the values of revenues and costs during the last 5 years. Monte Carlo simulation is performed for 10,000 trials.

The result of the simulation is the NPV forecast for individual project financing scenarios. The simulation output is in the form of a histogram (Figure 6) or as a cumulative NPV

distribution function. Figure 5 shows the simulation outputs for both vehicle recovery methods, i.e., for electric buses and CNG buses as well as for all scenarios of financing investments from ESF resources. The results show the following:

- without ESF financial support, the investment is loss-making for both investment variants (NPV is a negative value). This means that even after 10 years of using the vehicles, the invested funds will not return;
- zero value of NPV is achieved at the level of support of about 10% for electric buses and at the level of about 3% for CNG buses;
- with a low level of ESF funding, the economic efficiency of investment in electric buses is lower than in CNG buses. This is due to higher investment costs for electric buses. On the contrary, with a higher level of support from the ESF, energy savings from the operation of electric buses are reflected and the economic efficiency of the investment is growing faster;
- with ESF co-financing rate of about 25%, the NPV will equalize when investing in electric and CNG buses, and a further increase in the funding favours the purchase of electric buses over CNG buses.
- at the highest considered co-financing rate (90%), the NPV indicator reaches a value of almost EUR 4.9 mil. for electric buses and for CNG buses almost EUR 3.5 mil. (Figure 5).

Table 3. NPV at different levels of ESF funding

Indicator (EUR)	Level of ESF funding			
	0%	25%	50%	90%
NPV (Electrical buses)	-648,130	906,870	2,461,870	4,949,870
NPV (CNG buses)	-90,726	909,274	1,909,274	2,909,274

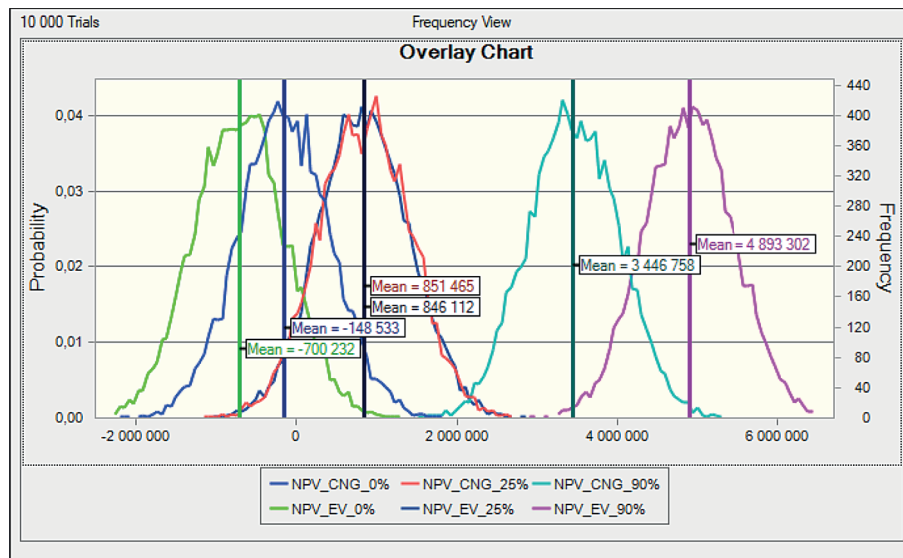


Figure 6. Histogram of NPV

The statistical parameters of the distribution function indicate the forecast reliability and the degree of agreement between the calculated NPV and the simulation output. The histogram in Figure 6 represents the simulation output at 0% ESF funding. It can be seen from Figure 7 that for EV the calculated NPV does not differ significantly from the simulated one. It is higher by EUR 52,000. The probability of achieving the NPV at least at the calculated level is 46%. It is similar for CNG, when the probability of achieving the calculated NPV is 45%. The simulation output acquires a similar result in other financing scenarios (Table 4). The standard deviation (σ) is an indicator of the forecast reliability, and, in our view, also the risk indicator. The standard

deviation is almost the same for electric buses and CNG buses (Table 4). And for each funding scenario, it is worth around EUR 564,000. In terms of risk, it is possible to interpret this statistical indicator, that the NPV acquires values from the “mean NPV $\pm \sigma$ ” interval with a certainty of approximately 68%.

Another output of the risk analysis is sensitivity analysis. Based on the sensitivity analysis, we can identify those risk input variables whose uncertainty is the most transferred to the uncertainty of the NPV forecast. According to Figure 8, the riskiest factors from revenue items are city subsidy (they contribute 33% to the total forecast uncertainty) and revenues from the sale of one-off tickets (share of the total NPV uncertainty 23%).

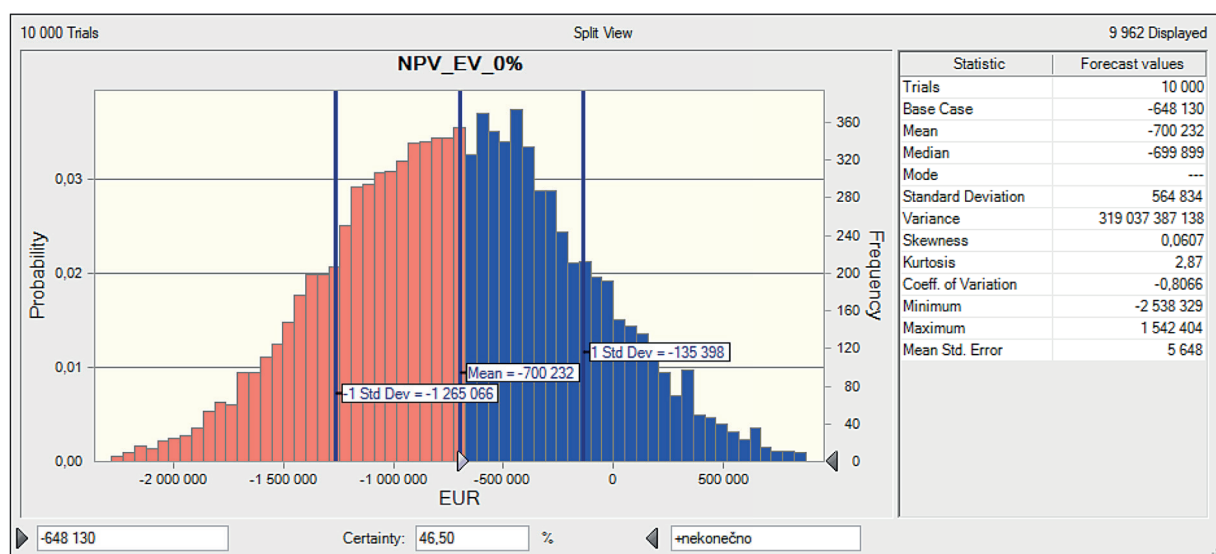


Figure 7. NPV histogram: e- buses, ESF funding 0%

Table 4. Results of NPV simulations

NPV statistical parameters (EUR)		Level of ESF funding			
		0 %	25 %	50%	90 %
Electrical buses	Mean NPV	-700,232	846,112	2 445 184	4,893,302
	Standard deviation [EUR]	564,834	563 034	555 356	564 624
CNG buses	Mean NPV	-148,533	851,456	1 846 994	3,446,758
	Standard deviation [EUR]	567,893	564,026	561 196	565 061

From the cost input variables, personnel costs are this, which contribute to the overall NPV uncertainty of 23%. The outputs of the sensitivity analysis for the individual investment financing scenarios did not yield fundamentally different results, so we present charts for only one financing scenario for both investment variants (Figure 8).

Tornado analysis is used to assess the impact of individual input variables on the total value of output. The impact of an individual change of all input variables identified as risk factors and defined as assumptions is examined. This means that if these revenues or expenses are characterized by variability, their variability poses a risk of achieving the expected NPV. From the tornado analysis (Figure 9), factors such as city subsidy, personal costs, and revenues from tickets significantly affect the uncertainty and the value of NPV. Both in the positive and in the negative direction. Depending on whether they increase or decrease NPV (i.e. whether they are cost or revenue items). Tornado analysis is performed to assumptions change within ± 10%. From Table 5, we see that a decrease in city subsidy by 10% causes a decrease in NPV from EUR (-648,130) to (-4 675 686), on

the contrary, an increase would increase NPV to EUR 3 288 883, which is a very high output sensitivity to this input.

CONCLUSION

Investing in green technologies is often costly. It follows not only from high input investment costs but also from risk factors and their effect in the long term. The effectiveness of green investments is not a priority at the economic level but at the environmental level, which is problematic to express financially. Therefore, based on purely economic analysis, they appear to be unprofitable. But in the long run and terms of sustainability, they are a social necessity.

The analysis of the purchase of ecological vehicles for a public transport company was presented in the article. The aim was to assess the project in terms of economic efficiency, monitored by the NPV indicator, and in terms of risks. The analysis was based on the real data from the company operating in urban public transport. The need to renew part of the

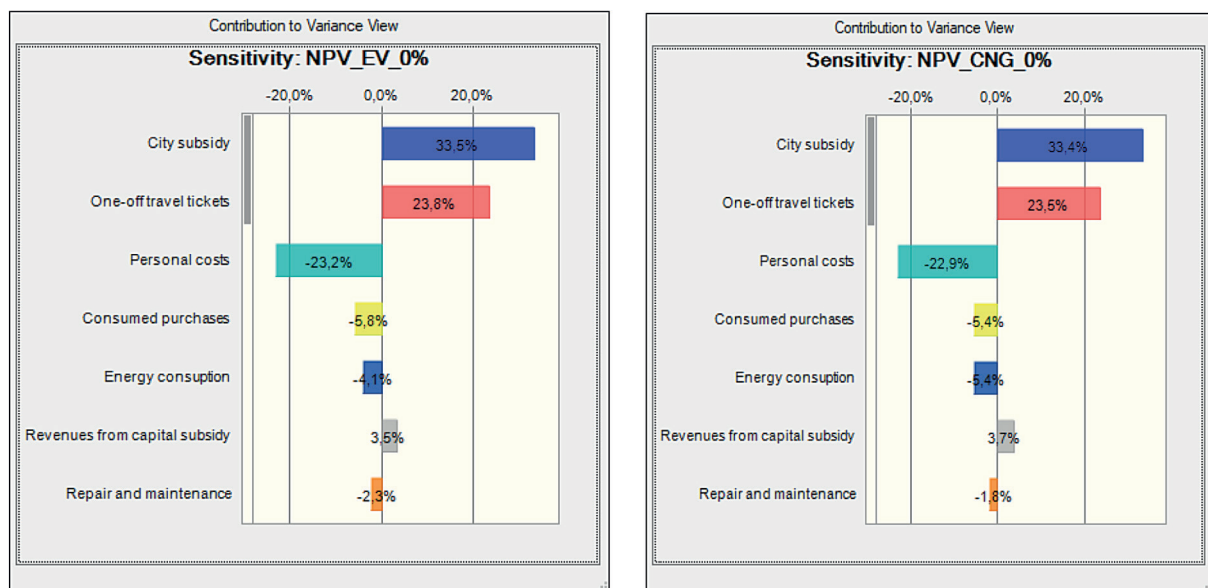


Figure 8. Sensitivity analysis NPV

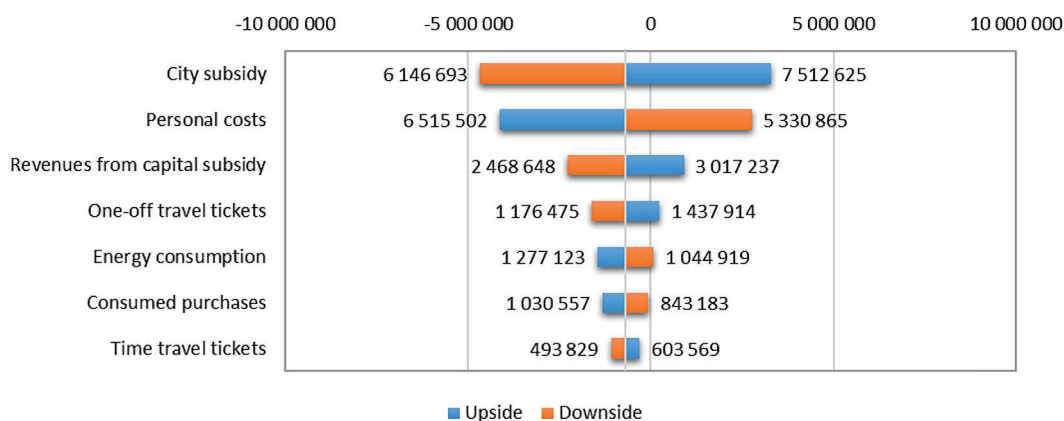


Figure 9. Tornado analysis: e-buses, ESF funding 0%

vehicle fleet and the real state of the company’s revenues and expenditures was the starting point. Under these conditions, two purchase alternatives (electric buses and CNG buses) were developed. Due to high capital expenditures, the analysis considered the intention to obtain ESF funding to co-finance the project. Several financing scenarios for the investment have been developed. The input variables that most affect the economic efficiency, and thus the investment project success, were considered as risks. The efficiency of the investment was assessed by Monte Carlo simulations, with the output being NPV.

The analysis showed that the project is highly loss-making without financial support from the ESF. The purchase of electric buses would result in higher losses than the purchase of CNG. With the ESF funding, economic efficiency has increased rapidly. The situation changed at a low rate, with NPV reaching positive values with ESF funding of 10% (electric buses) and 3% (CNG). With ESF funding of around 25%, the NPV for EV and CNG leveled off, and with higher support, EVs were more economical than CNG buses. Of the input variables, the riskiest were those that accounted for the largest share

of costs or revenues and whose uncertainty is the most transferred to the NPV forecast uncertainty. These effects were examined through sensitivity and tornado analysis.

In conclusion, we can state that investments of this nature are loss-making without support from non-repayable sources. With a low level of support, it is more economical to procure CNG buses. With a higher level of financial funding, investments in electric buses are more profitable due to lower operating costs. The research presented a detailed analysis of the economic efficiency of green investment in urban public transport. Although the analysis considered risks in addition to the economic aspect, it does not cover the problem of green investment comprehensively, and we are aware of the limits of research. The research did not consider important environmental benefits such as CO₂ reduction rates, exhaust emissions, and other environmental impacts caused by the exclusion of diesel vehicles from urban transport. Several variants of vehicle charging and the establishment of charging stations for EVs have also not been developed. These and possibly other factors that could affect the total cost of ownership will be the subject of future research.

Table 5. Results of Tornado analysis: e-buses, ESF funding 0%

Risk factors	NPV_EV_0%		Input	
	Downside	Upside	Downside	Upside
City subsidy	-4 675 686	3 288 883	6 146 693	7 512 625
Personal costs	2 760 329	-4 147 132	5 330 865	6 515 502
Revenues from capital subsidy	-2 292 776	905 972	2 468 648	3 017 237
One-off travel tickets	-1 625 658	238 854	1 176 475	1 437 914
Energy consumption	74 991	-1 461 794	1 044 919	1 277 123
Consumed purchases	-58 324	-1 328 479	843 183	1 030 557
Time travel tickets	-1 084 719	-302 084	493 829	603 569

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