Research Article

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Assessment of investment in electric buses: A case study of a public transport company

<https://doi.org/10.1515/eng-2021-0089>

received June 18, 2021; accepted July 24, 2021

Abstract: This case study presents an assessment of the efficiency and risk of the vehicle fleet renewal in the public transport company. The investment project is solved in two alternatives. The first alternative consists of vehicle replacement by only electric buses. In the second alternative, a combination of electric buses and CNG buses is considered. Assessment of the economic efficiency of the investment project is based on the net present value (NPV). Due to lower initial and ongoing capital expenditures, the second alternative is more cost-effective than the first one although the profitability of the investment project is low. Within risk assessment, sensitivity analysis points out the subsidy and personal costs as the risk factors influencing variance of NPV the most. Finally, the effectiveness of the investment project is assessed at different levels of the use of financial support from EU funds and the state budget. In that case, even a low level of financial support significantly increased the profitability of the project.

Keywords: green investing, electric buses, transport, simulation

1 Introduction

The EU aims to achieve climate neutrality by 2050. The European Green Deal supports, among other measures,

investments in environmentally friendly technologies and the introduction of greener, cheaper and healthier forms of private and public transport [1–4]. Strategies of local authorities and urban transport companies, as well as the urban transport organization itself, play an important role in introducing low-emission vehicles into public transport [5].

In the professional literature, several authors [6,7] address the issue of introducing low-emission vehicles into public transport for reasons of improving air quality in the city, reducing noise pollution, and subsequent passenger satisfaction. The authors [8] present the compilation of a fleet electrification plan in a cost-effective way, taking into account investment costs (IC), operating costs, and investments in charging infrastructure. This problem is modelled as an integer linear problem. Krawiec [9] emphasizes the need for correct formulation and description of the process of conversion of the public transport fleet and recommends the use of methods such as identification model based on statistical methods, optimization model based on multi-criteria optimization methodology, interaction model based on discrete Markov chain methods and economic models, allowing a realistic consideration of the proposed solution based on simulation methods.

Several authors focus on technical and economic evaluation and mutual comparison of variants of bus fleet renewal in public transport in order to increase its environmental friendliness. This problem is solved in different ways. Pietrzak and Pietrzak [10] identify and analyse the economic impacts of the implementation of zero-emission buses in the city. Meishner and Sauer [11] examine four technological concepts for the introduction of electric buses. From a technical point of view, they are considering charging batteries in a very fast and medium-demanding way, charging overnight and powered via an overhead contact line/battery (trolleybus hybrid buses). The economic evaluation is based on the total cost of ownership (TCO) and risk consideration is through sensitivity analysis. Topić et al. [12] have developed a simulation tool for bus electrification planning, which allows one to calculate the optimal type and number of electric buses, charging stations and to predict TCO, including ICs and operating costs.

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Topal and Nakir [13] proposed a dynamic model based on TCO for diesel, CNG and electric buses. They assessed the economic efficiency of the investment options using the financial criteria net present value (NPV), internal rate of return and payback period. The authors have shown that price differences in the purchase prices of buses can be offset by savings in operating costs for electric buses. Thus, the trend of sustainable public transport is moving towards the concept of electric buses. The economic efficiency of the replacement of electric bus batteries, including the sensitivity analysis, is addressed by Zhang and Chen [14] and the analysis of scenarios in ref. [15].

Dahlgren and Ammenberg [16,17] used the multi-criteria assessment (MCA) method to assess the sustainability of bus transport technologies, which includes technical, economic, environmental and social performance. MCA is implemented for various bus technologies, i.e. powered by diesel, hydrogenated vegetable oil, fatty acid methyl ester, ethanol, and natural gas (biomethane and electricity). Ankenman et al. [18] and Zitricky et al. [19] propose an integrated resource planning framework, taking into account investment and operating costs and an aggregation strategy for optimizing the charging of electric buses on different routes.

The aim of the paper is to assess an investment in the vehicle fleet renewal in a public transport company. The economic efficiency of the investment project is assessed via the NPV indicator and using Monte Carlo simulations.

2 Case study description

This case study examines the effectiveness and risk of investing in fleet renewal in a transport company. The

Košice public transport company (DPMK) operates public transport in the form of bus and tram transport. The transport company has a total of 216 buses. There are 23 electric buses and the others are for compressed gas or diesel. For accounting, the service life of buses is calculated at 10 years but many are used longer. The operation of old vehicles is unsatisfactory in terms of quality, safety, reliability and, last but not least, in terms of ecology. DPMK currently operates 32 buses older than 10 years for regular passengers transport. We consider their replacement with new vehicles to be the necessary minimum regarding the renewal of the vehicle fleet. The structure of the vehicle fleet is shown in Figure 1.

Due to the preference of the ecological aspect when choosing vehicles, the purchase of electric buses or buses on compressed natural gas is being considered. The following alternatives are considered for the purchase of new vehicles:

- ALT1: Replacement of end-of-life buses with SOR NS 12 electric buses.
- ALT2: Replacement of buses after a lifetime with a combination of SOR NS 12 electric buses and SOR NBG 18 CNG buses, which are a more environmentally friendly alternative to diesel buses and at the same time cheaper than electric buses.

3 Materials and methods

When evaluating the investment in the renewal of the vehicle fleet, we use the published annual reports of DPMK [20], which provide basic information on the company's management, the amount and structure of costs and revenues. The most important income and expense

Figure 1: The fleet structure [20].

Table 1: Selected revenue and expense items for the period 2016–2019 [20]

Indicator in EUR		2016	2017	2018	2019
Revenues	Revenues from one-off travel tickets	3,561,117	3,291,580	3,293,922	3,558,402
	Revenues from time travel tickets	5,397,057	5,355,451	5,302,868	5,738,533
	Revenues from invoiced transport	1,025,727	927,017	881,024	1,110,869
	Revenues from travel tickets via SMS	937,215	958,771	973,617	1,128,382
	Revenues from electronic valet	1,627,677	1,564,154	1,544,120	1,665,749
	Other revenues	6,708	2,920	1,122	1,243
	Subsidy from the city budget	16,020,000	17,263,860	19,176,076	20,700,000
Costs	Consumed purchases (material, fuel, energy, etc.)	8,201,876	9,957,963	11,046,737	11,295,190
	Services	2,193,201	1,932,475	2,602,575	2,131,209
	Personal costs	15,820,283	16,365,672	18,391,858	19,894,813
	Depreciations	7,177,784	7,586,674	7,771,557	7,604,470
	Other costs	3,336,092	2,602,684	2,540,309	1,553,412

items, which represent the most important component of cash flows (CFs), are presented in Table 1.

The investment in fleet renewal will be assessed on the basis of the financial indicator NPV (1), which will be forecasted using the Monte Carlo simulations technique:

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

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

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

In determining the statistical characteristics of probabilistic functions of risk variables, we use the development of economic variables for previous periods. The risk factors for which the parameters of the distribution function were set are in Table 2. The distribution used is

BetaPERT, which has been defined by likeliest, minimum and maximum values. Using Monte Carlo simulations, the uncertainty of these risk factors is transferred to the uncertainty of the NPV calculation, thus integrating the investment risk into the overall investment assessment.

As mentioned above, in alternative 1, all decommissioned buses will be replaced by electric buses. Electric buses are about 2.5 times more expensive compared to diesel buses. In addition, when operating transport, it is necessary to take into account the time for charging vehicles, which shortens the time available for their operation. For this reason, it is not possible to replace diesel buses with 1:1 electric buses but it is necessary to increase the number of vehicles; in our case, we are considering an increase of 15%, i.e. the number of purchased buses is increased to 37.

In alternative 2, the renewal of vehicles is considered by purchasing partly electric buses and partly CNG buses. Buses with a capacity of up to 100 people will be replaced by nine electric buses (15% higher than the number of decommissioned buses) and buses with a capacity of 150

Table 2: Probability distributions and statistical parameters in EUR

Variables	Probability distribution	Parameters		
		Min.	Likeliest	Max.
One-off travel tickets	BetaPERT	3,500,000	3,700,000	3,800,000
Time travel tickets	BetaPERT	5,300,000	5,700,000	6,000,000
SMS tickets	BetaPERT	1,200,000	1,300,000	1,400,000
Electronic valet	BetaPERT	1,550,000	1,600,000	1,700,000
Subsidy	BetaPERT	19,000,000	20,700,000	22,000,000
Consumed purchases	BetaPERT	10,000,000	11,200,000	12,000,000
Personal costs	BetaPERT	17,900,000	19,800,000	21,500,000
Services	BetaPERT	1,900,000	2,131,000	2,200,000

Table 3: Number of buses after lifetime and alternatives for their renewal

Current types of buses				ALT 1			ALT 2			
				Electric buses			Electric buses + CNG buses			
Type	Number (pcs)	Drive	Capacity (persons)	Type	Number (pcs)	Capacity (persons)	Type	Drive	Number (pcs)	Capacity (persons)
Solaris Urbino 15	24	diesel	150	SOR NS 12	37	105	SOR NBG 18	CNG	24	150
Solaris Urbino 12	2	diesel	100				SOR NS 12	EL	9	105
Tedom C12	5	CNG	88							
Karosa B732	1	diesel	90							

people will be replaced by CNG buses in the same number as decommissioned buses (24 vehicles in total). The method of fleet renewal for individual alternatives is in Table 3.

The mathematical model for the calculation of NPV is developed for 10 years, which is the expected service life of vehicles. For electric buses, it is necessary to consider that the battery has a shorter lifespan and needs to be replaced after approximately 6 years. Due to this, the additional one-off investment in new batteries must be expected after the 6th year, which is estimated at EUR 80,000. The estimated price of the electric bus is EUR 589,000 and that of the CNG bus is EUR 400,000. In the mathematical model for the calculation of NPV, an appropriate amount of costs and revenues belonging to the renewed part of the vehicle fleet is considered, which represents 15% of the total costs and revenues. Only the costs of consumed purchases, in which the fuel has the largest share, have changed. As the electricity costs for electric buses represent approximately 30% of the fuel costs for diesel buses, these costs have therefore been reduced by a coefficient of 0.4 for diesel buses and by a coefficient of 0.6 for CNG buses.

When evaluating the investment, the cash income from the sale of decommissioned buses is further considered. At an average price of EUR 5,000 per used vehicle, the cash income from the sale of vehicles will be EUR

160,000. One-off ICs for the procurement of buses and the replacement of batteries are in Table 4.

4 Results

4.1 Forecast NPV: ALT1 and ALT2

By using Monte Carlo simulation, we obtained a forecast of NPV for a period of 10 years (Figure 2). According to the results, it is clear that even after 10 years of using electric buses, the CF from the investment will not have a positive value. The mean value of the NPV indicator is EUR (−3,841,346). The indicator of investment risk is the standard deviation (σ), which amounts to EUR 1,184,999. In practice, this represents a 68% reliability of reaching the NPV level in the range of EUR (−2,656,347) to (−5,026,345). Exceeding the calculated value of NPV (−3,414,357) is, according to the simulation, probably only 37%.

The calculation of the NPV forecast for alternative 2 is also for 10 years. With this method of vehicle replacement, the NPV will reach a positive value after 10 years of life, the mean value of the NPV is EUR 2,142,973. The standard deviation is EUR 1,197,267. The range of NPV

Table 4: One-off ICs for individual alternatives

	Vehicle type	Price (EUR/pc)	Number (pcs)	ICs: 0th year (EUR)	Number of batteries (pcs)	Price (EUR/pc)	ICs: 6th year (EUR)
ALT 1	SOR NS 12	589,000	37	21,793,000	37	80,000	2,960,000
ALT 2	SOR NS 12	589,000	9	5,301,000	9	80,000	720,000
	SOR NBG 18	400,000	24	9,600,000	0	0	0

Figure 2: Histogram NPV pre-ALT1 NPV histogram for ALT1.

values for the mean $\pm \sigma$ interval is EUR 945.706 to 3,340,240. The histogram of the NPV prognosis is in Figure 3.

CF at ALT1 is negative throughout the lifetime of the investment whereas at ALT2 it is positive since the 9th year. An overview of the accumulated discounted CF for the entire lifetime period for both alternatives is in Table 5.

The sensitivity analysis (Figure 4) points to those risk factors whose uncertainty most influences the uncertainty of NPV. The figure presents risk factors that contribute to the NPV variance of more than 1%. According to simulations, they are revenues from the city subsidy and personnel costs. These items are also the highest in terms

of their total value. Subsidies contribute both in ALT1 and ALT2 to the NPV variance in about 50% and personnel costs in 44%. The third factor contributing to the total NPV variance is different. In ALT1, they are returns from time tickets, and in ALT2 it is consumed purchase.

4.2 Evaluation of NPV: financing with the EU and the state financial support

High ICs and probable loss, or at the best low return on investment, motivate companies to look for other sources of financing for investments in vehicles. EU pressure to

Figure 3: NPV histogram for ALT2.

Table 5: Accumulated discounted CF over the lifetime of the investment

Year	CF in '000 EUR									
	1	2	3	4	5	6	7	8	9	10
ALT1	-20,055	-18,318	-16,427	-14,383	-12,190	-12,269	-10,234	-8,091	-5,841	-3,414
ALT2	-13,403	-11,898	-10,231	-8,403	-6,420	-5,464	-3,645	-1,711	336	2,513

introduce clean public transport vehicles and to replace existing diesel buses with alternative propulsion vehicles, namely low- or zero-emission vehicles, is accompanied by opportunities for financial support from EU funds, which transport companies also use. For example, the Transport enterprise of the city of Zilina or Bratislava

Transport Company used funds from the EU and the state budget to purchase electric buses, which covered up to 95% of investment expenditures.

Such support will significantly change the company's financial situation and the return on investment. Figures 5 and 6 show NPV forecasts for both alternatives

Figure 4: Sensitivity analysis. **Figure 5:** NPV_ALT1 at different levels of investment financing support.

Figure 6: NPV_ALT2 at different levels of investment financing support.

if 25, 50, 75, and 95% finance support of investment has been used. From the overlay charts in Figures 5 and 6, we can see that the support of 25% leads to a positive NPV value for ALT1 after the 10th year. With the funding support of 95%, NPV will increase up to EUR 16,889,778. With ALT2, the NPV is growing slower than in ALT1, and with 95% funding support, NPV reaches almost the same level.

5 Conclusion

The EU's requirements under the European Green Deal also apply to intra-city road public transport. Reducing emissions from public transport is only possible by replacing the currently most widely used diesel buses with vehicles powered by alternative propulsion, electricity, or compressed natural gas. However, the renewal of the vehicle fleet by electric buses is too expensive. For this reason, it is difficult to manage this investment without the state support or support of European institutions.

The case study presents a proposal and assessment of an investment in the vehicle fleet renewal in the Košice public transport company. The investment project has been solved in two alternatives. The first alternative consisted of end-of-life vehicles replacement by electric buses. The economic evaluation of the investment was assessed

based on the NPV indicator. Assuming that the company's activities will be financed only by current resources (own resources and city subsidies), the NPV did not reach a positive value even after the 10th year of life. In the second alternative, the renewal was made by the combination of electric and CNG buses.

Due to lower initial and ongoing capital expenditures, the second alternative was more cost-effective than the first one. NPV was positive at the end of life, but it was not until the 9th year of life that the discounted accumulated CF turned positive. Different levels of financial support from other sources (EU funds and the state budget) were also examined. With the financing support of 95%, which is funding that other transport companies used for the purchase of electric buses, NPV reached a value of more than 16 mils EUR for both alternatives. But even a lower level of support has significantly improved the efficiency of the investment. That should motivate transport companies to apply for these resources and contribute to sustainable low-emission public transport with clean vehicles.

Acknowledgements: This work was supported by grant projects VEGA 1/0600/20, VEGA 1/0638/19, KEGA 012TUKE-4/2019, VEGA 1/0340/21 and KEGA 009TUKE-4/2020.

Conflict of interest: Authors state no conflict of interest.

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