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IMPLEMENTATION STRATEGIES FOR SUSTAINABLE VEHICLE FLEET MANAGEMENT

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Abstract

Research purpose. Against the backdrop of climate change, pressure is growing in the transport sector to reduce CO_2 emissions. Numerous companies are therefore setting specific targets to curb the CO_2 emissions of their own vehicle fleets. As a rule, this requires the replacement of combustion vehicles by vehicles with alternative drives. In addition to the selection of suitable technologies, economic aspects play a prominent role in this transformation process. Based on a practical case study, potential implementation strategies for achieving a specific CO_2 target are to be examined for a parcel service provider. The focus here is on a fleet of diesel combustion vehicles from the small van class with a permissible total weight of fewer than 3.5 tons, which are to be replaced by vehicles with electric drive (BEV) in order to achieve a specific CO_2-savings target. The research objective can be easily extended if one considers, on the one hand, that climate protection cannot be limited to individual countries but has to take place on a global level and, on the other hand, that sustainable strategic planning of vehicle fleets also concerns other vehicle segments, such as company cars for individual transport or trucks with higher permissible gross weights.

Design / Methodology / Approach. In the first step, framework conditions and criteria are defined that are needed for an evaluation of the implementation strategies. In the second step, a practical case study is constructed. In the third step, different scenarios and strategies for the conversion of the vehicle fleet are designed in order to achieve the set CO_2-emission targets. In the last step, the economic and ecological effects of the different strategies and scenarios are measured and analysed with the help of the calculation tool "DIPO-tool", which was developed at the Ludwigshafen University of Business and Society LUBS for research and teaching purposes. To evaluate sustainability, in addition to the established metrics for Tank-to-Wheel (TtW) and Well-to-Wheel (WtW), a holistic life cycle approach is implemented that takes into account emissions during vehicle production.

Findings. Against the backdrop of expected further technological development and numerous parameters with a considerable leverage effect on economic and ecological evaluation criteria, it seems advisable from the point of view of sustainability to use alternative drives as soon as possible. From the point of view of economic efficiency, a more differentiated picture emerges depending on the framework conditions, e.g., subsidies.

Originality / Value / Practical implications. The originality of the approach lies in the application of a practical case study and the attempt to reduce the complexity of the decision problem by using an Excel-based calculation tool. The value of the study lies in the realisation that, due to the complexity, a simple optimisation approach does not seem viable but rather the evaluation and analysis of different scenarios. The practical impact can be described in the sense that the used DIPO-tool can provide effective support for sustainable implementation strategies for vehicle fleets.

Keywords: Case study; CO_2-management; Corporate Social Reporting Directive (CSRD); Fleet management; Sustainable mobility

JEL codes: R40; Q56

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Introduction

Against the backdrop of climate change and increasingly concrete political measures such as the EU ban on new combustion engine cars from 2035, there are more and more companies that are defining concrete targets for reducing CO_2 emissions. To this end, numerous studies deal with the topics of sustainable transportation modalities and alternative drives. A joint study by HERE Technologies, DHL and the Bundesvereinigung Logistik e. V. examines the areas of CO_2 accounting, alternative drives and actions for sustainability in B2B-transport logistics with the project "Sustainability in transport logistics - fleets and alternative traction" (BVL, n.d.). The question is which departments influence electric vehicles procurement decisions in small and medium-sized enterprises (SME), in large-scale enterprises (LSE) and in public organisations (PO), and what are the differences compared to these departments' influences on internal combustion engine vehicles (ICEV) procurement decisions is the focus of a study conducted by Karlsruhe Service Research Institute (KSRI) at the Karlsruhe Institute of Technology (Guth et al., 2017). Another research direction is decision support through simulations. For this purpose, a study provides results based on the evaluation of 81 empirical mobility patterns of commercial fleets (Schmidt et al., 2021).

The focus here is particularly on companies that provide end-customer-related services, as consumer awareness of climate-friendly products, services, and processes is steadily increasing. These companies include parcel service providers, which have grown steadily in recent years as a result of e-commerce and have been given an additional boost by the corona pandemic.

The research objective of this paper is to analyse the effect of different procurement strategies for vehicles with alternative drives in terms of economic efficiency and sustainability. The research hypothesis is that it is possible to achieve defined climate protection goals and, at the same time, achieve an economic advantage through the selection of a specific procurement strategy. Methodologically, the calculation tool DIPO-tool is used to calculate the economic efficiency and sustainability of vehicles (Bongard et al., 2022). On the one hand, the results indicate that it is indeed possible to reconcile sustainability and economic efficiency goals. However, on the other hand, it also becomes clear that the results depend on a large number of parameters whose future development will be increasingly difficult to predict.

Literature Review

In 2021 alone, around 4.42 billion parcels were transported to recipients throughout Germany. This represents an increase of just under 8% compared with the previous year (Lehmann, 2021a; Lehmann, 2021b). If we look at the German top 5 parcel services based on their parcel volume (DHL [48%], Hermes [16%], UPS [12%], DPD [10%], and GLS [7%]), they have a combined market share of 93% (Meitinger, 2021). The German courier, express, and parcel services industry is one of the top performers in Europe, recording revenues of €18.9 billion in 2020. The visible increase in demand in online retail is forcing parcel service providers to adapt quickly to new circumstances (Lehmann, 2021a). There are also additional challenges, such as mandatory delivery times in the form of same-day delivery or overnight delivery (Bundesverband Paket und Expresslogistik e. V., 2021). Experts predict that the online trend will continue after the Corona pandemic, resulting in a further increase in parcel orders (FAZ, 2021; Schlautmann, 2021). Particularly on the last mile of the delivery process, there is the possibility of using CO_2-neutral delivery vehicles in the form of electric vehicles (BMWK, 2023a; DHL, 2023).

The reasons for this are the alternatives to internal combustion vehicles that are now available on the market and which, in terms of their intended use and general economic conditions, appear to be fundamentally suitable for completing emission-free tours on the last mile.

In the present work, the target of the market leader DHL that 60% of the vehicle fleet for the "last mile" should consist of fully electric vehicles by 2030 (BVL, n.d.) is taken as a basis. For the purposes of the paper, this target is formulated as a saving of direct CO_2 emissions in operation, so-called Tank-to-Wheel emissions (TtW), of 60% in 2030 compared to the base year 2022 for the fleet of the case study.

Numerous other parcel service providers (Imarc, 2023) are also looking at strategies to reduce emissions from their fleet of vehicles. Aramex has reduced fleet emissions by 20% from 2016 to 2020 and plans a long-term strategy to convert its entire fleet into electric vehicles where possible (Aramex, 2020). FedEx has even more ambitious goals. From 2025, FedEx wants to procure half of its delivery vehicles to be electric and 100% from 2030 (Werwitzke, 2021). UPS has a strategic goal of achieving CO_2 neutrality by 2050. There are no specific targets for electric vehicles, only the announcement that electric vehicles are part of the plans to improve environmental sustainability through a fleet of alternative fuel vehicles and advanced technology (FedEx, 2022).

The aim of this work is to use a case study to evaluate various strategies for achieving objectives with regard to economic and ecological criteria and, in particular, to take account of the framework conditions that are to be assumed. Against the backdrop of an increasingly unstable and uncertain corporate environment, a scenario-oriented approach is thus pursued that counters the mainstream of predictability of optimal solutions (Schwenker & Schencking, 2022).

The research hypothesis is that the vehicle fleet of a parcel service provider will be operated with 60% less CO_2 emissions in 2030 and that it is possible to determine an economically optimal procurement strategy for this. Different acquisition strategies for electric vehicles that are suitable for the intended use of a parcel service provider as well as different scenarios for important parameters, are to be investigated. Not only the target savings in 2030 are considered, but also the total CO_2 emissions over time until 2030.

The decision criteria are calculated using the DIPO tool, a professional solution for the holistic consideration of the economic efficiency and sustainability of vehicles in the field of fleet management and control. It consists of various Excel spreadsheets and was designed for teaching and research purposes at the Ludwigshafen University of Applied Sciences (Bongard et al., 2022; Bongard & Schröder, 2022) and continuously developed. In the expansion stage used, the calculation of LCA values, in particular, was advanced.

Due to the fact that individual countries cannot stop global warming caused by greenhouse gas emissions on their own, many countries have joined forces and agreed on common climate protection targets. The main goal is to greatly reduce greenhouse gases that are harmful to the climate, such as carbon dioxide, methane and nitrous oxide. The EU has committed itself to complying with the Kyoto Protocol adopted in 2005 for climate protection (BPB, 2020; UBA, 2013). The greenhouse gases emitted were to be reduced by 5.2% between the years 2008 and 2012 compared to the base year 1990 (UBA, 2013). The EU generated greenhouse gas savings of 8% during this period, exceeding this target. In the second commitment period between the years 2013 and 2020, the European Union set itself the goal of saving a further 20% of greenhouse gas emissions. This emissions reduction target was again significantly exceeded (EC, 2021).

The transport sector is receiving special attention. This sector has not yet been able to achieve the hoped-for reduction targets. In 2018, road freight transport emitted a total of 888 million tons of CO_2 and was thus responsible for around a quarter of all CO_2 emissions in the European Union (Eisenkopf & Knorr, 2021). Therefore, with the "Fit for 55" project, the EU wants to create new and, above all, more transparent specifications with regard to renewable energies and more effective energy efficiency. There should also be full integration into the emissions trading system (Schiffer, 2021). To this end, CO_2 certificates are to be traded in the transport sector from 2026 (Bundesregierung, 2021). Electromobility is the focus for achieving the climate targets. Increased use is to be made of climate-neutral means of transport with the appropriate infrastructure and, at the same time, an improvement in the economy is to be achieved as a result of the COVID-19 pandemic (Eisenkopf & Knorr, 2021; EU, 2022; Schiffer, 2021).

The German government has anchored future greenhouse gas reduction targets in the Federal Climate Protection Act. By 2030, 65% fewer emissions are to be emitted compared to the base year 1990. Then, 15 years later, no more greenhouse gases are to be emitted (BMWK, 2023b). To combat greenhouse gas (GHG) emissions, the federal government is promoting electromobility until the end of 2025. To this end, nearly two billion euros in innovation premiums for the purchase of electric vehicles will be passed on to buyers. In addition, the charging infrastructure for electric vehicles is to be expanded (BMWK,

2023a). The Federal Ministry of Economics and Climate Protection's subsidy program stipulated that purely battery electric vehicles can be subsidised up to a maximum net base list price of €65,000 with the condition that the vehicle model is listed on the list of eligible vehicles. The total subsidy for the purchase of a battery electric vehicle consists of three blocks (these are applied in equal parts): Environmental bonus from the state, innovation premium (until the end of 2022) and environmental bonus from the vehicle manufacturer (Energy Agency, 2023). Vehicles with an acquisition price of up to €40,000 will receive a total subsidy of €9,000 (all three parts to be applied), while vehicles with an acquisition price of over €40,000 and up to €65,000 will receive a total subsidy of €7,500 (all three parts to be applied) (BAFA, 2023). From 2023, only battery-electric means of transport that make a positive contribution to climate protection will be subsidised (Energieagentur, 2023).

As a result of the Russian Federation's war of aggression on Ukraine, Germany's energy dependence on Russia is becoming clearly noticeable. To compensate for the resulting disadvantages, the expansion of renewable energies is to be accelerated (BMWK, 2022). This will lead to electromobility experiencing a more robust upswing in the future.

Criteria for the economic efficiency of vehicles mainly concern the acquisition costs minus any subsidies and the residual value of a vehicle to be achieved, as well as running costs such as energy consumption or maintenance and repair costs. Numerous sources are available for a comprehensive consideration of economic efficiency criteria (Bertram & Bongard, 2014; Hacker et al., 2015; Wietschel et al., 2019).

When considering ecological sustainability, the literature uses generic terms such as life cycle assessment (LCA) or environmental accounting. These terms holistically encompass the phases of production, use and recycling or disposal of products (Koch et al., 2020). Other terms commonly used in this context are "Well-to-Tank (WtT)", which covers greenhouse gas emissions on the production side from the source to the vehicle tank, and "Tank-to-Wheel (TtW)", which stands for a purely consumption-based view. The term Well-to-Wheel (WtW) is the sum of energy and vehicle processes, i.e., indirect WtT- and direct TtW-emissions (Schmied & Mottschall, 2014). For this purpose, the terms "Cradle-To-Cradle" and "Cradle-To-Grave" refer to the entire life cycle, which in the case of Cradle-To-Cradle aims towards reuse (recycling) and in the case of Cradle-To-Grave towards disposal. The basis for the calculations is conversion factors as CO_2-equivalents (Schmied & Mottschall, 2014.). The conversion factors each refer to one type of energy and are used as TtW-CO_2e factor for the calculation of direct TtW-emissions, as WtT-CO_2e factor addition as a surcharge for the upstream chain, and as WtW-CO_2e-factor for the calculation of WtW-emissions. In this work, the CO_2-emissions TtW, WtW and an LCA surcharge for the vehicle manufacturing process are used as the decision criterion for assessing sustainability.

Research Methodology/Case Study

The supply chain of parcel service providers is characterised by the operation of regional delivery depots downstream to the end customer. The delivery depot in the case study has ten diesel-powered internal combustion vehicles and serves a region with a population of approximately 11,000. The depot has an area of 200 square meters. Parcel deliveries are made to both urban and rural areas. In the latter case, deliveries are made in a "compound", i.e., parcels and letters are delivered together. Deliveries are made in ten districts, each of which has a dedicated vehicle. Up to 150 parcels are delivered per district every working day. The route lengths vary from a few kilometres for districts close to the depot to 50 km for the most distant district. The average distance driven per vehicle is assumed to be 30 km/day. Since deliveries are made six days a week, this results in 312 operating days per year. Taking holidays into account, 302 operating days are assumed. Multiplying the average distance per vehicle by the 302 operating days results in a total mileage per vehicle of 9,060 km/year. This mileage serves as the reference value for further calculations. For the purpose of this work, peak loads, which can occur especially before holidays such as Easter or Christmas, are not considered. In 2022, the fleet will consist of ten Volkswagen T6 vehicles built in 2021 (Fig. 1). To achieve the set goals, the acquisition of a fully electric alternative in the form of an Opel Vivaro e-Cargo L is being considered (Fig. 2).



Fig. 1. Volkswagen T6 2.0 TDI BMT (Source: https://www.alle-lkw.de/transporter/kastenwagen/volkswagen-t6-2-0-tdi-transporter-navi-pdc-klima-a6929803.html)



Fig. 2. Opel Vivaro-e Cargo L (Source: https://www.opel.de/nutzfahrzeuge/vivaro/vivaro-e/uebersicht.html)

Both vehicles are fit for the purpose. The economic life is set at six years for depreciation purposes for both vehicles. The following assumptions are made for the calculation of the TCO (Table 1):

Table 1. TCO parameters for the base year 2022 (Source: author's compilation)

Cost components	Parameter name	Parameter unit	VW T6 (ICE)	Opel Vivaro (BEV)
Vehicle				
Net list price	P_list_price	Euro	€29,270	€37,490
Fuels/Energy				
Fuel consumption Diesel	P_fuel_consumption	Litre/100 km	10.147	
Power consumption	P_electricity_consumption	kWh/100 km		31.855
Other Costs				
Vehicle tax	P_veh_tax	Euro/p.a.	€160.00	€0.00
Vehicle insurance	P_veh_insurance	Euro/p.a.	€828.00	€596.43
Maintenance, service and care & Administration	P_veh_maintenance_repair_care	Euro/p.a.	€656.88	€457.66

The manufacturer's fuel consumption data was adjusted for practical calculations (Hacker et al., 2015). Due to the numerous start and stop operations of the delivery vehicles, an additional consumption of 39% is assumed for the combustion vehicle and of 15% for the BEV.

The data are processed with the DIPO tool (Bongard et al., 2022). For reasons of clarity, a detailed presentation of the calculations is omitted. The structure of the research design is outlined in the following figure (Fig. 3). The DIPO tool uses the TCO data of the two vehicles for calculating the cost and CO_2 values of the vehicles, taking into account one of the three scenarios in each case. These values are then transferred to a Strategy calculation worksheet, in which the relevant procurement strategies are mapped.

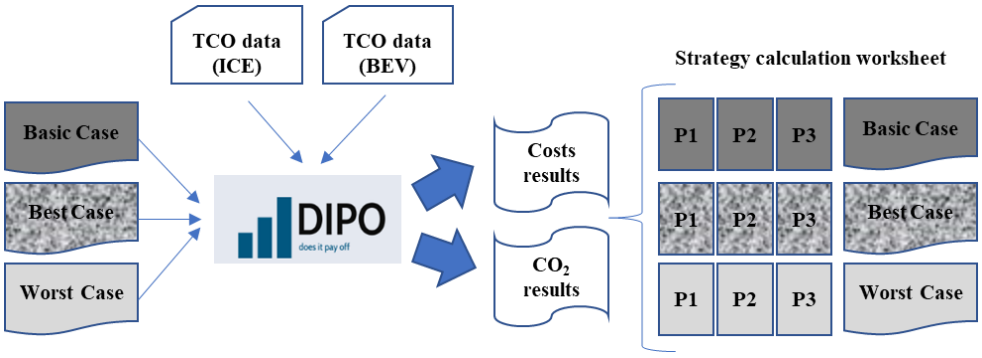


Fig. 3. Research design scheme (Source: author's compilation)

Target value calculation

To calculate the target value for fleet emissions in 2030, the amount of 24.5 tCO_2 is calculated for the ten diesel vehicles in the reference year 2022. This results in a target value of CO_2 emissions of the vehicle fleet in 2030 of 9.8 tCO_2. Since the emission target only refers to TtW emissions, the constellation of the vehicle fleet in the target year is easy to determine. 60% of the vehicle fleet, i.e., six vehicles, must be electrically powered. Three different strategies are to be pursued to achieve this target value in 2030.

Procurement Strategy 1 (P1)

In this strategy, the intention is to acquire alternative vehicles with the electric drive as quickly as possible in order to benefit from the subsidies that are granted in Germany. In the base year 2022, the premium for the BEV is €9,000. The number of vehicles purchased should be six. This will reduce the capital required for the acquisition, and, on the other hand, the company will continue to have proven combustion technology at its disposal.

Procurement Strategy 2 (P2)

This strategy involves purchasing six alternative vehicles as late as possible in 2029. This means that the subsidies are foregone, but capital is conserved, and there is also a chance that the purchase prices for BEVs will fall in the future as a result of technological developments.

Procurement Strategy 3 (P3)

With this strategy, the acquisition of the six alternative vehicles is spread over several years. Two vehicles are to be purchased in the base year and two more in 2026 and 2029. This strategy spreads the capital requirements over several years and also aims to benefit from the subsidies in 2022 and lower purchase prices over the years up to 2029.

Against the background of the numerous crises and unforeseeable developments of the recent past, there are discussions about whether one should not introduce in the management economics a departure from the computation of optimal solutions and turn more to the computation of scenarios (Hacker et al., 2015, Schwenker & Schencking, 2022). This view is followed here, and in this respect, three different scenarios are assumed for the different procurement strategies, which refers to the development of important parameters.

Basic Case

The basic case assumes moderately falling prices for BEVs and, at the same time, steadily rising diesel prices.

Best Case

The best-case scenario underlines an optimistic development for BEVs. Purchase prices fall sharply due to technological developments, and, at the same time, the price of diesel rises while the price of electricity falls.

Worst Case

In the worst case, the general conditions for BEVs deteriorate. Purchase prices and the price of electricity rise, while the price of diesel falls.

Assumptions are now made for various parameters for the different scenarios (Table 2):

Table 2. Scenario parameter (Source: author's compilation)

				Scenario	**1**	**2**	**3**
		Value in			Basic Case	Best Case	Worst Case
		2022	2026	2029	Price/ Inflation factor p.a.	Price/ Inflation factor p.a.	Price/ Inflation factor p.a.
Residual value	VW T6 (ICE)	€23,000	€15,000	€10,000			
Net list price	Opel (BEV)	€37,490			-2.0%	-5.0%	+5.0%
Subsidy		€9,000					
Fuel price in Euro/Litre		€1.80			+1.5%	+3.0%	-3.0%
Energy price in Cent/kWh		€0.50			+2.0%	-3.0%	+3.0%
Other costs					+5.0%	+2.0%	+10.0%
Present value discount rate		+5.0%					

For the decommissioned combustion engines, sales revenue is achieved in each case, which decreases in the course of the years. For the other parameters, certain values are assumed depending on the scenario. For the calculation of profitability, the calculation is dynamised by taking into account a calculation interest rate for discounting future cash inflows and outflows.

Results

The defined data are processed with the DIPO tool. In addition to CO_2 emissions, numerous other values are calculated as target values for the various procurement strategies in the context of fleet management. For clarity reasons, only selected results are indicated separately after sustainability and economy. In principle, the desired savings target can be achieved with all procurement strategies. However, there are significant differences when looking at the cumulative CO_2 emissions over time. The total sum of emissions (Fig. 3) is calculated from the WtW-values plus an LCA-share for the manufacturing phase. These shared values are 8.5 tCO_2 for the combustion vehicle and 19.8 tCO_2 for the BEV, which in turn are distributed proportionally over 13 assumed years of use (Wietschel, 2019). For electricity generation, a WtT-addition value of 421 gCO_2/kWh was considered (Helms et al., 2019).

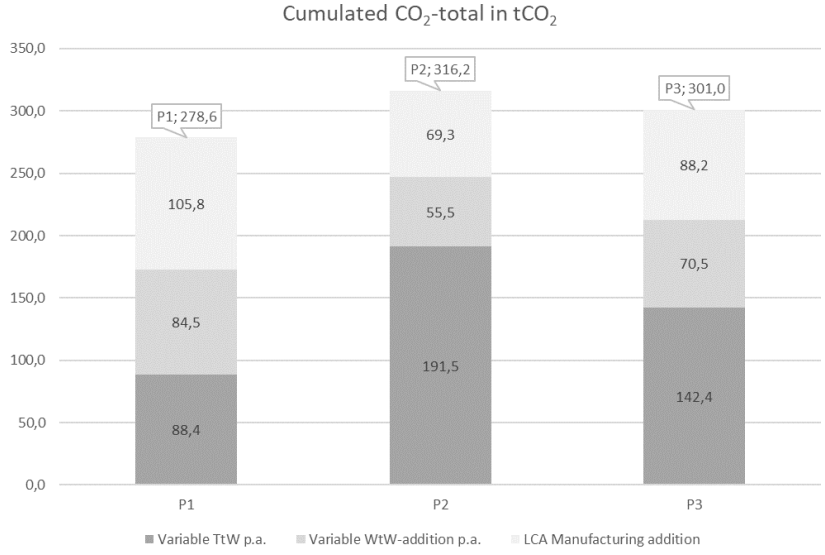


Fig. 4. Results procurement strategies (Source: author's compilation)

As can be clearly and comprehensibly seen, from the point of view of climate protection and sustainability, the best strategy is to procure BEVs as quickly as possible (P1) since the other strategies

mean significant additional CO_2 emissions. Significant for strategy P2 is the high share of direct TtW-emissions.

In advance, it can be stated that the research hypothesis was confirmed that with the selection of a certain procurement strategy, one could achieve both the sustainability goals and gain an economic advantage over alternative procurement strategies.

In the following figures, the most economically advantageous procurement strategies are indicated by the addition of "Lowest value" in brackets. For the evaluation of economic efficiency, three criteria are used. To reflect on the scenario-based approach, the results are grouped by scenario.

The first criterion is TCO, which consists of depreciation and amortisation and cash-out costs, which are mainly fuel and electricity, respectively (Fig. 5).

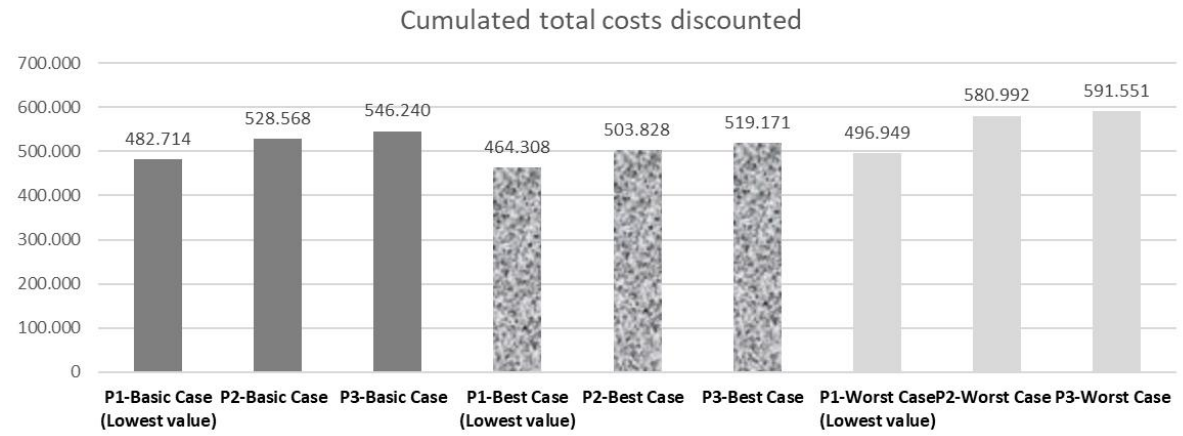


Fig. 5. Results cumulated total costs discounted (Source: author's compilation)

In each of the assumed scenarios, strategy P1 is the best option when considering TCO as an evaluation criterion.

The second criterion is only concerned with the costs affecting disbursement, which are mainly attributable to fuel or electricity (Fig. 6).

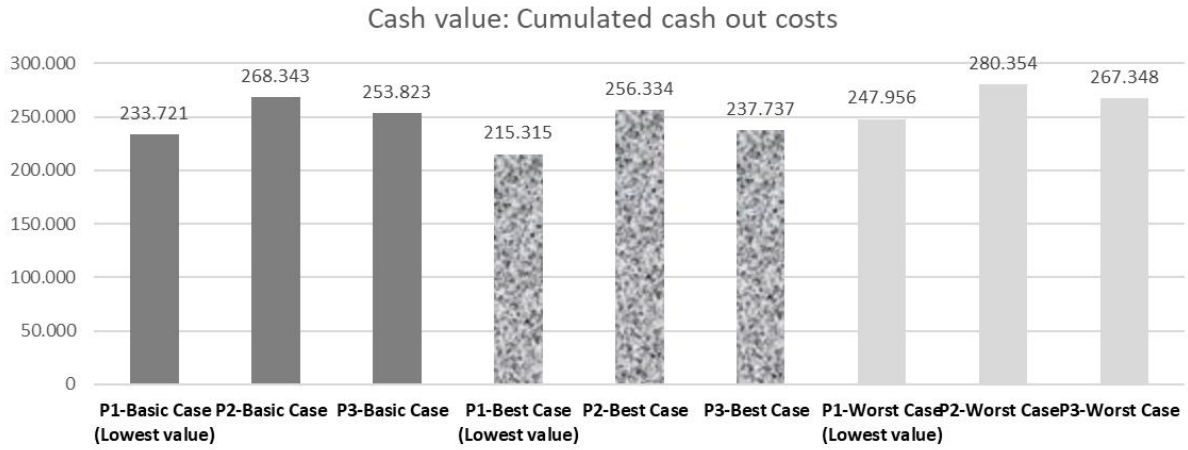


Fig. 6. Results cumulated cash out costs (Source: author's compilation)

Even with this economic efficiency criterion, P1 is the best procurement strategy in each of the assumed scenarios.

For the third criterion, an attempt was made to examine the effect of the subsidies paid in 2022. For this purpose, the criterion of cumulative investment was used, which means the discounted balance of payments for the purchase of BEVs and proceeds from the sale of combustion vehicles (Fig. 7).

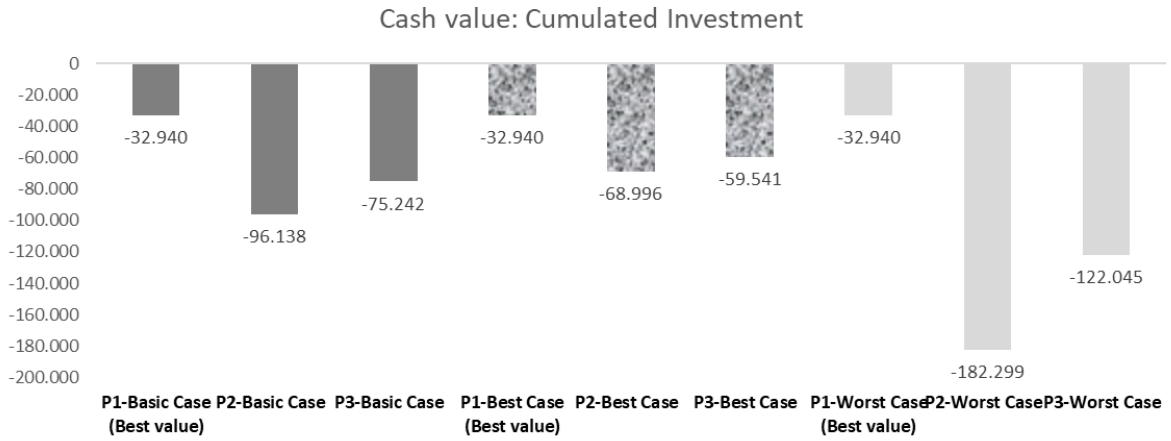


Fig. 7. Results cumulated investment with subsidy (Source: author's compilation)

With the subsidies, P1 is again the optimal strategy from an economic point of view since, in each scenario, the balance shows the lowest value. Without taking the subsidy into account, the picture is more differentiated (Fig. 8).

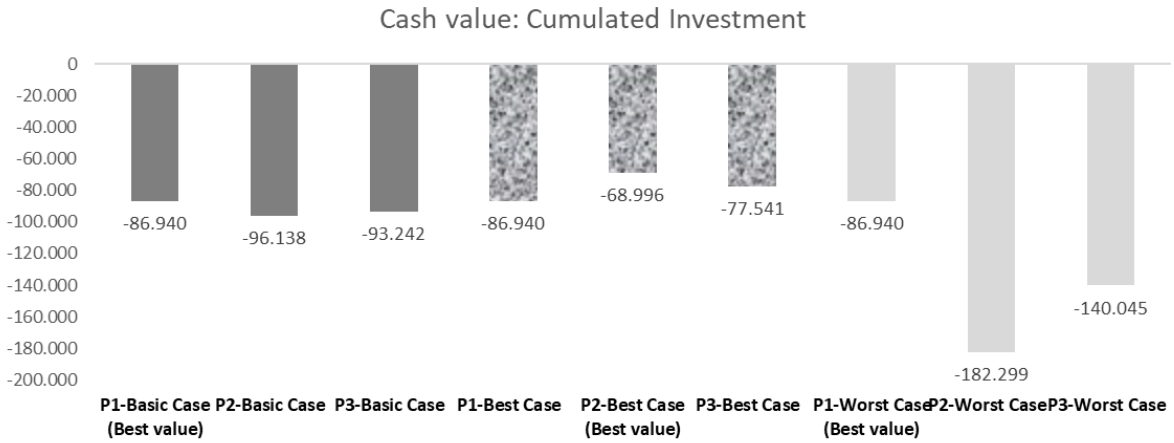


Fig. 8. Results cumulated investment without subsidy (Source: author's compilation)

Only under the assumption of the basic case or worst-case scenarios would strategy P1 be economically more advantageous. If the best-case scenario is taken into account, strategy P2 represents the optimal strategy. In this respect, the classical decision conflict between economic rationality and sustainability results here since the procurement strategy P2 exhibits the highest emission values of all procurement strategies.

Conclusions

As the most important realisation, one can state that the definition of CO_2-emission targets cannot be considered only on a goal year but under the inclusion of the accumulated emissions up to the reaching of the goal year. The achievement of set emission targets under the premise of selecting economically optimal procurement strategies is possible but subject to the planned development of the set parameters. The implementation of such a scenario-based fleet planning to achieve defined emission targets under the premise of economic efficiency is a very complex matter, characterised by a large number of

parameters and influencing factors to be considered. Numerous studies underscore the global relevance of this issue. An example of such studies comes from McKinsey & Company on the decarbonisation of US fleets (Chauhan et al., 2023). The challenges of balancing six different trade-off factors, such as the fastest route to greenhouse gas compliance and stakeholder expectations (factor 2) and the lowest cost of delivery to the customer (factor 5), are examined in a study by management consultants Roland Berger (Roland Berger, 2023). A global study on the electrification of fleets has been presented by the consultancy PTOLEMUS, which examines the market segments of company cars, light commercial vehicles, heavy goods vehicles and buses in six continents (PTOLEMUS, 2022).

The simultaneous calculation of TCO and CO_2 emissions based on recorded vehicle data by the DIPO tool has simplified this planning process considerably and reduced the effort to an acceptable level. A particular advantage arises from the fact that any changes to parameters, such as the elimination of subsidies, are immediately available to recalculate all relevant results for determining sustainability and cost-efficiency. Thus, this tool also underlines a future scope for the current developments in the area of reporting obligations for companies, which the EU enacted in 2022 with the Corporate Social Reporting Directive (CSRD) (BMJ, 2023). The next development step of the DIPO tool is to be able to design scenarios for the development of the CO_2-WtT-surcharges as well. This takes into account the fact that many countries would like to change the existing conventional electricity mix in favour of lower- CO_2-electricity generation. One option is renewable energies, but another is the controversial nuclear energy.

Restrictions in this research area arise mainly from the availability of relevant information, as many underlying values, such as procurement values or mileage, are not accessible internal company data. Future challenges for research in this area include, on the one hand, technological developments in the field of vehicle technology, where it can be assumed, for example, for electric vehicles, that better technical performance will become available at the same purchase price. On the other hand, the volatility of essential framework conditions is likely to play a role, such as energy prices or inflation. In addition, it must be taken into account what role government regulations will play in the future.

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