

THE ECONOMIC DIMENSION OF THE ELECTROMAGNETIC PROCESS – COMPARISON STUDY OF COSTS OF REPAIRS OF ELECTRIC VEHICLES AND POWERED WITH CONVENTIONAL FUELS

Wojciech Lewicki

West Pomeranian University of Technology in Szczecin, Faculty of Economics
Żołnierska Street 48, 71-290 Szczecin
tel.: 914496500, fax: 914496950 e-mail: wojciech.lewicki@zut.edu.pl

Abstract

The development of electro-mobility in Poland is one of the inevitable processes awaiting the Polish automotive industry. For each potential electric vehicle user, the information on the vehicle's operating costs therefore becomes an imperative of tremendous importance. The analysis of market prices of passenger cars clearly indicates that the costs of acquiring a new electric vehicle are much higher than conventional fuel vehicles. Therefore, the expectations of customers themselves become fundamentally significant, who in relation to the spare parts in the case of this category of vehicles expect the highest technological and quality standards while maintaining the suitable price parameter.

The article attempts to signal the issues related to the evaluation of electro-mobility parameters by presenting the comparative study of the costs of repairing electric vehicles and vehicles fuelled by conventional fuels. Considerations were supplemented by authoritative cost simulations, including the comparison of the same models of vehicles equipped with both the conventional and ecological power units. The aim of the article is to draw attention to the essence of the research problem and to answer the question whether the total costs of operating electric vehicles are in reality significantly lower than that of vehicles fuelled by conventional fuel.

Keywords: *electro-mobility, alternative power sources, conventional fuels, operating costs, economic dimension, repair costs, spare parts*

1. Introduction

In today's reality, in the age of ubiquitous market competition, almost all car dealers' sales offer more and more often have electric vehicles, apart from conventional or hybrid vehicles. According to many automotive industry experts, this trend is a global phenomenon and it affects almost every market segment, regardless of whether the manufacturer has had experience in manufacturing these cars or whether it is his debut on this market.

The prevailing notion in the available literature is that in the case of electric vehicles, their operating costs are significantly lower than those of conventional diesel engines are. Thus, knowledge of the economic factors influencing the development of the popularity of this vehicle group is becoming a very significant imperative in today's market realities. In particular, in the context of the promoted electrification process of the Polish motorization by the Polish authorities.

In the quest to define the factors influencing the development of the electro-mobility phenomenon, we encounter a number of conceptual and theoretical obstacles in the literature on electric vehicles, which result in the lack of clear visibility of the basic parameter in the form of repair costs, and thus the cost of spare parts. The potential and magnitude of the electrification process is best illustrated by a forecast indicating that around 500 million electric vehicles out of 2 billion vehicles in the world will be moving on the roads in 2040. Consequently, the rapid increase in the demand and supply should be expected in relation only to electric vehicles; but also to repair services. Against the background of academic considerations, one should ask the questions of what actual costs of operation should be expected in case of the potential repair of such a car? Thus, the problem of estimating the economic parameters of electro-mobility is an

important research problem, given that the available literature both in the field of technical and economical sciences there are no such analyses and studies in the interdisciplinary sense.

The presented approach has become the basis for the adoption of boundary conditions and the methodology aimed at measuring the economic impact of the electro-mobility process on the cost of repairs of the operation electric vehicles and fuelled by conventional fuels by:

- discussing the essence of the operating costs of electric cars in economic terms,
- comparison of costs of repair of operational conventional and electric vehicles offered by the same vehicle manufacturer.

The main objective of the article is to verify the thesis promoted in the literature concerning lower costs of repairs of operational electric vehicles compared to those fuelled by conventional fuels.

2. The essence of the operating costs of electric cars and the cost of spare parts

In the age of ubiquitous market co-operation, electric car manufacturers increasingly emphasise the role of the parameter defined as “*low operating costs*” in their advertisements, thus emphasising the superiority of their product over the competing products. Sales marketing specialists, however, do not specify what these costs are. One of the definitions available in the literature indicates that maintenance is a technical and economic process undertaken with its manufacture, sale of the object or system, and it ends with its withdrawal. However, according to the author, in today’s market realities this definition does not fully reflect the essence of the subject matter examined, in particular with regard to the operation of electric vehicles. Therefore, when undertaking an attempt of academic considerations in this matter, it is important to that the maintenance of electric vehicles in practice is defined as a set of targeted organizational, technical and economic activities of people with the vehicle, and relations occurring between them from the moment the vehicle is accepted for use for its intended purpose, until its liquidation [15].

The problem of the use of electric vehicles, as indicated by the available technical literature, comes down to, among others:

- using,
- handling,
- diagnosing,
- fixing,
- maintenance and storage,
- possible decommissioning, as the disposal of used parts and consumables,
- recycling and development of individual parts and components.

On the other hand, while referring to the concept of costs, this concept is expressed as a value in the literature of economic sciences, as the necessary use of the business entity’s resources in order to obtain a certain useful effect. While navigating within the concepts characteristic for accounting, the cost may be considered the reduction of benefits in the accounting period with the reliably defined value in the form of reducing assets or increasing liabilities and provisions, which will lead to the reduction in equity in a manner different from the withdrawal of these resources by shareholders or owners [11]. Thus, these definitions do not fully explain the essence and concept of the so-called operating costs of electric vehicles. At this stage of considerations, it should be mentioned that the definition of this category of costs in the field of economic sciences on the basis of the above-discussed definitions raises serious problems of a formal and methodological nature. According to the author, however, this problem can be solved through the interdisciplinary perspective on this unique category of costs.

Understanding the essence of operating costs in relation to electric cars primarily comes down to understanding the mere essence of the operating process of these vehicles, so in order to maintain the operational potential through the life of the vehicles and ensure its safe and efficient use, the applicable financial resources are needed. Of course, both the rime period and the scale of

these financial resources is not the same and it depends on the determinants of technical and non-technical nature, among the most important ones we can list:

- the technology applied in terms of energy storage,
- availability and technical condition of the charging infrastructure,
- charging time,
- vehicle age,
- type of vehicle,
- technical condition,
- way of usage,
- frequency of usage,
- human factor,
- condition of the surface,
- weather conditions,
- availability of services,
- cost of spare parts,

It is noteworthy that the growing importance in terms of operating costs of electric cars has recently been paid in professional literature to the parameter defined as the cost of spare parts. It is not a new thing that the cost of repairs and the prices of materials used during repairs are interrelated, which means that low prices of spare parts often determine the low cost of operation of the given model or vehicle.

Summarizing the present issues, taking into account only the theoretical aspect of the economic dimension of the electro-mobility process, it can be mistakenly assumed that for the given vehicle model, the type of the installed power unit, i.e. whether it is an electric or conventional engine, should not affect the cost of spare parts. Meanwhile, the studies presented below illustrate the real trends in the price of original spare parts for electric cars on the Polish automotive market.

3. The economic analysis of the costs of repairs of the operational electric vehicles and vehicles fuelled by conventional fuel

The complexity of mechanical work, the specification of materials used, and the differentiated repair technology of both electric and conventionally fuelled vehicles require an experimental approach. Therefore, the author in his simulations has used the preconceived patterns of behaviour in order to show the relevant relationships. Therefore, further considerations will not be given to the qualitative assessment of the components or their classification and analysis of the individual service costs consisting of the total cost of repair of the vehicle, and only the total costs of repairing the selected vehicles will be presented from the strictly selected market segments. In addition, for the purposes of this study, it has been simplified that the cost of repair is the sum of the service costs and prices used for the repair of the spare parts.

At the very beginning, in order to maintain the logical correctness and methodological value of the study, it was assumed that:

- the scope of research covered the selected car model from the given market segment. The vehicle manufacturer was selected for the analysis, who has the same vehicle model both with the electric and combustion engine in his sales offer. The selected models were the most popular among the customers and the highest number of items sold in 2016 on the Polish market,
- this vehicle was subject to the individual repair process provided for by the particular manufacturer,
- in order to estimate the repair costs, a specialised expert program called AUDATEX was used, supporting the numerical experiment with the cost estimation method, as it is currently the only method used in the practice of operating repairs of passenger cars in Poland,

- considering the considerable scope of repairs carried out in repair workshops, it was assumed that the cost analysis would concern the spare parts from three basic components of the vehicle: body, chassis and engine. For comparative purposes, in each case, only the prices of new original spare parts were used from June 2017,
- to illustrate these dependencies, the repair costs were analysed in three main repair options: the first car was for the replacement of body components, such as front mudguards 2 pcs, engine compartment cover, front bumper. The second one was for the chassis parts, such as brake pads and discs 2 pcs, shock absorbers 2 pcs. While the third one will involve the replacement of the engine or the set of the drive unit,
- in the case of cost simulations, all variants of the parts assumed the average mechanical labour costs used at the authorised station of the selected vehicle manufacturer.

The presented assumptions have become the basis for the adoption of boundary conditions and methodology aimed at measuring the economic impact of the electro-mobility process on the costs of repairs of electric vehicles and vehicles powered with conventional fuels.

From the point of view of the correctness of maintenance and the possibility of capturing the necessary data, the results of the numerical experiment were presented in a tabular form Tab. 1 to 3.

Tab. 1. Analysis of the repair costs of the car of the body parts depending on the type of the drive unit mounted on the vehicle in PLN

Vehicle brand	VW Golf 1.4 5d diesel year of manufacture 2016	VW Golf-e 5d Year of manufacture 2016
Front fenders 2 pcs	1765 PLN	1765 PLN
Engine compartment cover	1345 PLN	1869 PLN
Front bumper	974 PLN	974 PLN
Cost of spare parts	4063 PLN	4608 PLN
Cost of labour	1675 PLN	1565 PLN
Total repair cost	5738 PLN	6173 PLN

It results from the above simulation that low costs of repair were observed for a vehicle powered by a spark engine. Moreover, the data analysis showed price divergence in terms of spare parts and labour. Despite the fact that vehicles are visually no different from each other, in the case of an electric vehicle, the price of the engine compartment cover is slightly higher. Original research on other brands and vehicle models confirm that this manufacturer is not isolated. It results from the use of lighter and more cost-consuming materials to reduce the weight of the vehicle and, in most cases, the outer body parts for the engine compartment cover. While the slight reduction of labour costs in the case of an electric vehicle results from a simplified construction in the front part of the vehicle.

Tab. 2. Analysis of the repair costs of the car of chassis parts depending on the type of drive unit mounted in the vehicle in PLN

Vehicle brand	VW Golf 1.4 5d Diesel year of manufacture 2016	VW Golf-e Year of manufacture 2016
Brake discs 2 pcs.	1256 PLN	1256 PLN
Brake pads 2 pcs.	409 PLN	409 PLN
Shock absorbers 2 pcs	1478 PLN	1809 PLN
Cost of spare parts	3143 PLN	3474 PLN
Cost of labour	890 PLN	890 PLN
Total repair cost	4033 PLN	4364 PLN

The above cumulative simulation shows that, once again, the lower repair costs were observed in the case of a vehicle powered by a spark engine. The data analysis showed slight differences in the amount for the cart of chassis parts depending on the drive unit mounted in the vehicle, with the exception of shock absorbers. However, it is worth emphasising that in this case there are no divergences in labour costs. In addition, the cost of spare parts for both vehicles can be reduced by using the so-called alternative parts

Tab. 3. Analysis of repair costs of the cart of engine parts depending on the drive unit mounted in the vehicle in PLN

vehicle brand	VW Golf 1.4 5d diesel year of manufacture 2016	VW Golf-e Year of manufacture 2016
Engine, set	26 456 PLN	32567 PLN + price of batteries cost 20.000 PLN
Cost of spare parts	26 456 PLN	52 567 PLN
Cost of labour	7543 PLN	5376 PLN
Total repair cost	33 999 PLN	57 943 PLN

The above cumulative simulation shows that, once again, lower repair costs were observed in the case of a vehicle with a spark engine. The data analysis showed significant differences in terms of prices for the engine cart depending on the type of the drive unit mounted in the vehicle, with the exception of shock absorbers. It is worth noting that when replacing a power unit in an electric vehicle, the vehicle manufacturer also recommends replacing the batteries in order to maintain full efficiency in terms of charging. Thus, the comparison of spare parts costs indicates that the replacement of the power unit in an electric car is almost two times more expensive than in a vehicle equipped with a spark engine. At this stage of considerations, it should be borne in mind that in the case of a conventionally fuelled vehicle, the vehicle manufacturer allows repair or replacement of individual engine components, for example, engine block, distribution and bushes, or the piston assembly. In addition, in this case we can talk about high availability of spare parts in the aftermarket. Therefore, the cost of repair can be significantly reduced. While with respect to an electric vehicle, correct technology does not allow for the possibility of repairing the engine and recommends replacing it potentially with a battery pack. Both the vehicle manufacturer and the aftermarket do not offer individual components of the engine, which leads to a significant increase in the cost of such repairs. However, it is worth noting that lower labour costs have been found, leading to the conclusion that the replacement of an electric motor is technically a less complicated process than of the spark engine.

Summary

As indicated by the available literature, the costs incurred with the operation repairs of cars are an indispensable part of their operation. They are crucial for the life span of a vehicle, not only in technical, but also economic terms. Failure to meet the replacement date for individual parts or components may in the future expose the owner of the vehicle not only to dangerous road conditions, but also to the substantial costs related to the repair of major failures. The analysis of current purchasing trends on the Polish automotive market clearly indicates that a slight increase in the sale of hybrid and electric vehicles has been noticeable recently. Vehicles in this market segment are associated in most cases with a high level of technological advancement and ecological lifestyle. On the other hand, the future owner of an electric vehicle from the given market segment rarely considers the costs of its operation, more precisely, the strategy of the development of prices of spare parts in the event of any service or collision repair. According to many experts in the automotive market, this factor should mainly decide on the choice and purchase of this type of vehicle, rather than the low cost of driving one kilometre. This does not change the fact that owning an electric vehicle is associated with a high cost of ownership, which,

along with a prolonged operating life, will lead to incurring higher and higher costs of its maintenance in order to maintain high technical efficiency. So, one of the determinants for selecting a vehicle, apart from the low cost of driving one kilometre, should include the analysis of prices of spare parts.

The analysis of the results of the numerical experiment presented in tables from 1 to 3, in relation to the repair costs of electric and flue gas vehicles, shows that:

- the cost of operating repairs influences the type of the power unit that is mounted in the given vehicle,
- there are price differences both in terms of spare parts prices, labour and total repair costs,
- with respect to an electric vehicle, the particularly high costs of repair during the operation process, relate to the replacement of the power unit.
- the savings in relation to electric vehicles were observed in terms of labour costs.
- the analysis of individual cost cards has undoubtedly shown that the operation process of an electric vehicle is more cost-effective than a conventionally fuelled vehicle.

Summing up, the reflections presented by the author on the impact of the economic dimension of the electro-mobility process – the comparative study of the costs of repairs of electric vehicles and the conventionally fuelled ones do not fully exhaust the substance of the problem, but are merely an attempt to signal the complexity of the analysed issues concerning the impact of individual power sources applied in passenger cars on the costs of their maintenance and prices of spare parts.

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