Article citation info:
Lewicki W. The case study of the impact of the costs of operational repairs of cars on the development of electromobility in Poland. The Archives of Automotive Engineering – Archiwum Motoryzacji. 2017; 78(4): 107-116, http://dx.doi.org/10.14669/AM.VOL78.ART8

THE CASE STUDY OF THE IMPACT OF THE COSTS OF OPERATIONAL REPAIRS OF CARS ON THE DEVELOPMENT OF ELECTROMOBILITY IN POLAND

STUDIUM BADAWCZE WPŁYWU KOSZTÓW NAPRAW EKSPLOATACYJNYCH SAMOCHODÓW OSOBOWYCH NA ROZWÓJ ELEKTROMOBILNOŚCI W POLSCE

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Summary

The development of electro-mobility in Poland is one of the inevitable processes certainly awaiting the Polish automotive industry. It is expected that in the next few years, electric cars will become a viable alternative to petrol cars. Available reports an studies indicate clearly that the costs of purchasing a new electric vehicle are much higher than a vehicle powered with conventional fuel. Therefore, the expectations of the customers themselves regarding the costs of the operation of such a vehicle, including the prices of spare parts, get the fundamental meaning at the stage of purchasing decisions.

The article attempts to signal the issue of the impact of the costs of operational repairs of passenger cars on the development of electromobility in Poland. The considerations were based on proprietary simulations of costs, including the comparison of the same vehicle model equipped with both conventional engine and ecological propulsion units. The aim of the article is to draw attention

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to the essence of the research issues undertaken and to answer the question, whether in reality the costs of operational repairs of electric vehicles are much lower than those that are fuelled with conventional fuels. The presented research results can certainly be helpful in the purchasing decision-making processes both for individual and group clients.

Keywords: electromobility, alternative power sources, repair costs, spare parts, operational costs

Streszczenie

Rozwój elektromobliności w Polsce jest jednym z nieuniknionych procesów, jaki z pewnością czeka polską motoryzację. Należy spodziewać się, że w najbliższych kilku latach samochody elektryczne staną się realną alternatywą dla samochodów spalinowych. Dostępne raporty i opracowania wskazują wyraźnie, że koszty nabycia nowego pojazdu elektrycznego są znacznie wyższe niż pojazdu zasilanego paliwem konwencjonalnym. Zatem fundamentalnego znaczenia na etapie decyzji zakupowych nabierają oczekiwania samych klientów w kwestii kosztów eksploatacji takiego pojazdu, w tym także cen części zamiennych.

W artykule podjęto próbę zasygnalizowania problematyki wpływu kosztów napraw eksploatacyjnych samochodów osobowych na rozwój elektromobliności w Polsce. Rozważania oparto o autorskie symulacje kosztów, obejmujące porównane tego samego modelu pojazdu wyposażonego zarówno w silnik konwencjonalny jak i ekologiczne jednostki napędowe. Celem artykułu jest zwrócenie uwagi na istotę podjętej problematyki badawczej oraz odpowiedź na pytanie czy w rzeczywistości koszty napraw eksploatacyjnych pojazdów elektrycznych są znacznie niższe, niż pojazdów zasilanych paliwami konwencjonalnymi. Zaprezentowane wyniki badań mogą być pomocne w procesach podejmowania decyzji zakupowych zarówno w przypadku klientów indywidualnych jak i grupowych.

Słowa kluczowe: elektromobilność, alternatywne źródła napędu, koszt naprawy, części zamienne, koszt eksploatacji

1. Introduction

Only a few years ago, electric cars were perceived only in the category of prototype vehicles, which had no chance of spreading, let alone for multi-series production. However, due to technological progress, increasing the range, shortening the charging time and reducing the cost of production, a dynamic development of the phenomenon of electromobility started to be discussed [14]. In a short time interval, almost all car dealers' sales introduced both hybrid and electric cars to their sales offer [1]. According to many automotive industry experts, this trend is a global phenomenon and it will affect almost every market segment, in case of passenger cars[13]. Regardless of the fact, whether the given manufacturer has had experience in manufacturing this category of vehicles or whether it will be his debut on this market[9].

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 [3]. This thesis, in most cases, is based only on the analysis of the parameter specified in the subject literature as the complete costs of TCO ownership [19]. 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 plan for developing electromobility promoted 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 operational 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 there will be as much as 1 million electric cars driving on the roads in Poland in 2025 [10]. As a consequence, 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 are the actual costs of the potential operational repair of such a vehicle? Thus, the problem of the effect of costs of operational repairs on the development of electromobility in Poland 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 approach presented above has become the basis for the adoption of boundary conditions and the methodology aimed at measuring the impact of the costs of operational repairs on the development of electromobility in Poland by.:

- discussing the essence of the operating costs of electric cars in interdisciplinary terms,
- the comparative analysis of operational repairs costs of a passenger car with the conventional, hybrid and electric drive offered by the same vehicle manufacturer.

While the main aim of the article is to try to answer the question whether in reality the costs of operational repairs of electric vehicles are much lower than those that are fuelled with conventional fuels. Achieving the indicated goal required the selection of appropriate research methods and techniques used in economic sciences. In order to achieve the effect of complementarity, all the considerations were supplemented with literature in the field of technical sciences, which gave the article an interdisciplinary character. The presented research results can certainly be helpful in the making of purchasing decisions both for individual and group clients.

2. The essence of the operating costs of electric cars – an interdisciplinary approach

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 are these costs [12]. One of the definitions available in the literature indicates that exploitation is a technical and economic process undertaken with its manufacture, sale of the object or system, and it ends with its withdrawal[17]. 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 not that the exploitation 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 [18].

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[15].

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[6]. 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 than the withdrawal of these resources by shareholders or owners [8]. 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 [5].

It is noteworthy that the growing importance in terms of the subject of operating costs of electric cars has recently been paid in professional literature to the parameter defined as the cost of spare parts[15]. 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 [2]. Therefore, the analysis of the prices of individual spare parts seems crucial in the process of determining the future costs related to the exploitation of vehicles powered also with alternative fuels.

Summarizing the present issues, taking into account only the theoretical aspect of the considerations concerning the economic factors that affect the development of electromobility, 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 and hybrid cars on the Polish automotive market.

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

The complexity of mechanical work, the specification of materials used, and the differentiated repair technology of both electric, hybrid and conventionally fuelled vehicles required 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 analysis of the durability of units, qualitative assessment of the components or their classification. The presented cost simulations focus on the 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 vehicle models 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 is the only one on the

Polish market to offer the same model of vehicles both with the electric, hybrid and combustion engine in his sales offer [7],

- each vehicle was subject to the individual repair process provided for by the particular vehicle 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 [4],
- considering the considerable scope of services carried out in repair workshops, it was assumed that the cost analysis will concern the spare parts from three basic components of the vehicle: body, chassis and engine [16].
- for comparative purposes, in each case, only the prices of new original spare parts were used from July 2017
- to illustrate these dependencies, the repair costs were analysed in three main repair options: the first cart 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 impact of the costs of operational repairs of passenger cars on the development of electromobility in Poland.

From the point of view of the correctness of exploitation 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 cart of the body parts depending on the type of the drive unit mounted on the vehicle in PLN

Vehicle brand	VW golf 1,5 TSI (petrol)	VW e-golf	VW Golf GTE hybryd
Type of drive unit	t.petrol 1498 cm^3 power: 110 kW/150 KM	electric power: 100 kW/ 136KM	t.petrol 1395 cm^3 power:110kW/150KM. electric power: 75kW/102KM
Front fenders 2 pcs.	1765 PLN	1765 PLN	1765 PLN
Engine compartment cover	1345 PLN	1869 PLN	1869 PLN
Front bumper	974 PLN	974 PLN	974 PLN
Cost of spare parts	4063 PLN	4608 PLN	4608 PLN
Cost of labour	1675 PLN	1565 PLN	1565 PLN
Total repair cost	5738 PLN	6173 PLN	6173 PLN

It results from the above simulation that lowest 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 costs. Despite the fact that vehicles are visually no different from each other, in the case of an electric and hybrid vehicle, the price of the engine compartment cover is slightly higher than in the case of a vehicle powered with the engine with the spark ignition. It results from the use of lighter an more cost-consuming materials to reduce the weight of the vehicle and, in most cases, the outer body parts, in the analysed case the engine compartment cover. Noteworthy is the fact of shaping the overall repair costs of the hybrid and electric model at the same level. While the stated slight reduction of labour costs in the case of an electric and hybrid in relation to the model with the engine with the spark ignition results from a simplified construction in the front part of the vehicle[16].

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

Vehicle brand	VW golf 1,5 TSI (petrol)	VW e-golf	VW Golf GTE hybryd
Type of drive unit	t. petrol 1498 cm^3 power: 110 kW/150 KM	electric power: 100 kW/ 136KM	t. petrol 1395 cm^3 power: 110kW/150KM. electric power: 75kW/102KM
Brake discs 2 pcs.	1256 PLN	1256 PLN	1256 PLN
Brake pads 2 pcs.	409 PLN	409 PLN	409 PLN
Shock absorbers 2 pcs	1478 PLN	1809 PLN	1809 PLN
Cost of spare parts	3143 PLN	3474 PLN	3474 PLN
Cost of labour	890 PLN	890 PLN	890 PLN
Total repair cost	4033 PLN	4364 PLN	4364 PLN

The above cumulative simulation shows that, once again, the lowest 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 (At this stage, it should be emphasized that in the case of a drive unit with a lower capacity and power, price differences may also apply to discs and brake pads). However, it is worth emphasising that in this case there are no divergences in labour costs. And the cost of spare parts in relation to the ones analysed above for vehicle models with ecological drives can be reduced by using the so-called alternative parts [11].

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 1,5 TSI (petrol)	VW e-golf	VW Golf GTE hybryd
Type of drive unit	t. petrol 1498 cm^3 power: 110 kW/150 KM	electric power: 100 kW/ 136KM	t. petrol 1395 cm^3 power: 110kW/150KM. electric power: 75kW/102Km
Engine, set	26 456 PLN	32567 PLN + price of batteries cost 20.000 PLN	23455 PLN +16956 PLN+ price of batteries Cost 8.000 PLN
Cost of spare parts	26 456 PLN	52 567 PLN	48 411 PLN
Cost of labour	7543 PLN	5376 PLN	8654 PLN
Total repair cost	33 999 PLN	57 943 PLN	57065 PLN

The above cumulative simulation shows that, once again, lowest 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 or hybrid vehicle, the vehicle manufacturer also recommends replacing the batteries in order to maintain full efficiency in terms of charging. In spite of the fact that the so-called battery life is determined as approx. 400 thousand km [7]. 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 [18]. In addition, in case of this category of repairs, 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 or hybrid vehicle, correct technology does not allow for the possibility of repairing the electric engine and recommends replacing it potentially with a battery pack. However, 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. While 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. At this stage of the considerations it should be noted that experts from the automotive market emphasize that their replacement of the electric motor will in most cases be a consequence of the post-collision damages rather than wear and tear processes [13]. In addition, in the case of a model powered by an electric motor, the cost of a warranty review after 30 and 60 thousand km is 5 times lower than in the case of a model with a conventional or hybrid drive [7].

4. Recapitulation

Currently, most car companies work on one or a whole range of electronic vehicles. Certainly in the next few years, in any market segment, apart from internal combustion engines, hybrid and electric drives will also be available. This means that every user will be able to find a car that suits his needs. The available literature lists the benefits of using electric vehicles, such as low noise emission compared to vehicles with internal combustion engines, lower risk of detonating the vehicle during a road collision and burns or burning of travellers or having a higher torque, which makes the road manoeuvres easier, thus increasing the active safety [13]. However, forgetting that these vehicles will require repairs and operational maintenance. As indicated by the available literature, the costs incurred with the exploitation repairs of cars are and will be an indispensable part of their operation[15]. They are crucial for the life span of a vehicle, not only in technical, nut 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[2]. 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[20]. 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. Although, over the years, manufacturers of electric vehicles will certainly introduce options in all their models that enable modular replacement of the battery or in some cases the possibility of their regeneration [9]. 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 and hybrid vehicle, the particularly high costs of repair during the operation process, relate to the replacement of the power unit – and precisely the prices of the parts, which is the power unit.
- the savings in relation to electric vehicles were observed in terms of labour costs.
- the cost analysis of individual cost cards has undoubtedly shown that the operational repair process of an electric and hybrid vehicle is more cost-effective than a conventionally fuelled vehicle.

Summing up, the reflections presented by the author on the impact of the operational repairs costs of passenger cars on the development of electromobility in Poland do not fully exhaust the substance of the problem, but are merely an attempt to signal the complexity of the analysed issues. However, the correctness of the proposed assumptions will certainly be verified by the market within a few years, which will allow for further assessment of the impact of the operating cost parameter on the purchasing decisions in the case of individual and group customers in relation to this category of vehicles.

The full text of the article is available in Polish online on the website http://archiwummotoryzacji.pl.

Tekst artykułu w polskiej wersji językowej dostępny jest na stronie http://archiwummotoryzacji.pl.

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