ARCHIVES OF TRANSPORT *ISSN (print):* *0866-9546*
Volume 48, Issue 4, 2018 ***e-ISSN (online):*** *2300-8830*
DOI: *10.5604/01.3001.0012.8367*

THE ASSIGMENT OF VEHICLE ASSESMENT BASED ON MULTI CRITERIA DECISION MAKING

Ewelina SENDEK-MATYSIAK[1], Dariusz PYZA[2]

[1] *Kielce University of Technology, Faculty of Mechatronics and Mechanical Engineering, Kielce, Poland*

[2] *Warsaw University of Technology, Faculty of Transport, Warsaw, Poland*

Contact:
1) esendek@tu.kielce.pl, 2) dpz@wt.pw.edu.pl

Abstract:

The degree of emission limitation achieved through improved efficiency of combustion engine vehicles can no longer set off additional emissions caused by increasing traffic activity. As the restriction of greenhouse gas emissions from cars is expected to be particularly difficult, the air pollution and excessive dependence of road transportation on oil cannot be improved without the implementation of new mobility concepts (biofuels, hybrid drives, electric vehicles). The lack of these concepts, as emphasized in the White Paper, will preserve transportation dependence on crude oil so deeply that only 10% of energy will be derived from renewable sources. According to this scenario, until 2050 the CO2 emissions in the transportation sector will increase by one-third compared to 1990. Moreover, there will be an increase in the costs of traffic congestion until 2050 by ca. 50%. The difference in the availability between central and peripheral areas and social costs of accidents and noise pollution will increase as well (EC, 2011). The goal of the paper is to determine whether the implementation of a new solution would actually improve the situation of air pollution, traffic noise, etc. To this end, the paper proposes a comparative analysis of cars with various sources of energy using a multi-criteria scoring method. Notably, this method has never been used in such a confrontation before. Until now, the multi-criteria assessment methods have been used i.a. to evaluate implementation variants for infrastructural investment projects in rail transport (Jacyna and Wasiak, 2007), traffic flow distribution (Jacyna and Merkisz, 2014; Wasiak et al., 2017), supply chain efficiency (Jacyna-Gołda et al., 2018), effectiveness of vehicle allocation for tasks in supply chains (Jacyna-Gołda et al., 2017), etc.

Key words:
electric car, automotive market, multi-criteria scoring method

To cite this article:

Sendek-Matysiak, E., Pyza, D., 2018. The assigment of vehicle assesment based on multi criteria decision making. Archives of Transport, 48(4), 77-85. DOI: https://doi.org/10.5604/01.3001.0012.8367

1. Introduction

The primary driver of technical, technological, and organizational development in all sectors of the economy is the environmental friendliness, i.e. the necessity to limit their environmental footprint.

According to studies, transportation has the greatest environmental footprint of all industries. Apart from the energy sector, the transportation has been the primary source of greenhouse gases emissions in the European Union for many years now and in 2016, it was responsible for 27% of their emissions (Fig. 1).

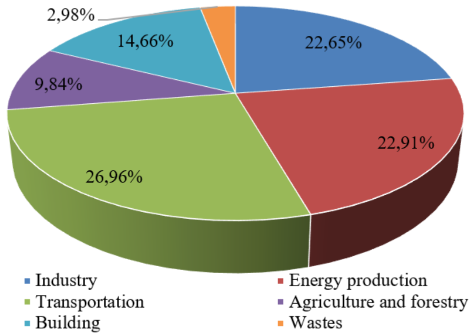

Fig. 1. Emissions of greenhouse gases in 2016 in the EU (EEA, 2017)

Approximately three-quarters of the emission from this economic activity are generated by road transportation, and in particular passenger cars (Fig. 2).

According to analyses, the amount of road transportation air pollution in the European Union has been growing since 2014, contributing to the increase in the total EU emissions (Fig. 3).

According to data from Eurostat (2018), the sector was responsible for 38.5% of the total NOx emissions, 38.2% of CO emissions, and 22.2% of particulate pollutants in the European Union in 2015 (Fig. 4).

In large cities, the share of road transportation in the total emissions of these pollutions is definitely higher and, as specified in Badyda (2010), in centers it may reach even up to 90%. In Warsaw, road transportation has the greatest influence on the quality of air (even 60–90% of pollutions are transportation-related) (Transport Publiczny, 2018). Unwanted effects of transport operation are environment and health degradation (Jacyna et al., 2017; Łukasik et al., 2017). World Health Organization (WHO) declares that ca. 90% of residents of the European Union cities are exposed to air pollution levels considered harmful to health (EEA, 2018).

Products of vehicle fuel combustion affect the natural environment, in particular on a local and regional scale, causing such phenomena as acid rains or photochemical smog and affecting the microclimate near roads.

Moreover, they pose a direct threat to human health. Harmful substances released to the atmosphere (such as particulate matter, aromatic hydrocarbons, including benzo[*a*]pyrene, sulfur and nitrogen oxides) have serious health effects such as asthma, allergy, COPD (chronic obstructive pulmonary disease), fertility disorders, premature births, low birth weight, lower IQ in successive generations, strokes, heart attacks, ischemic heart disease, and even diabetes or Alzheimer's disease. Most of these conditions lead to premature death.

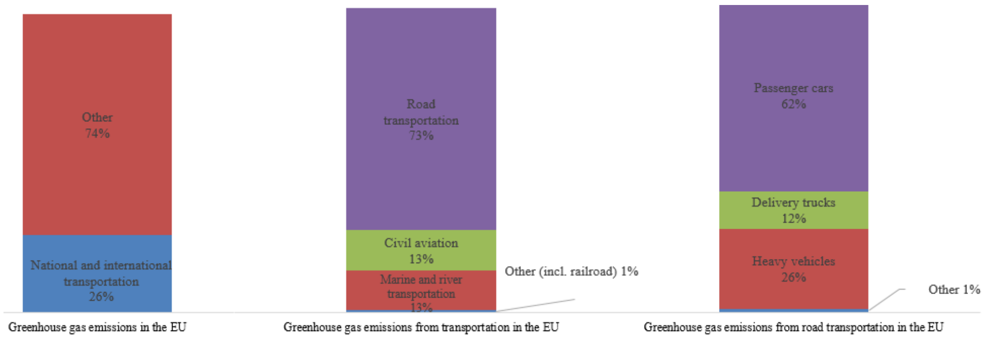

Fig. 2. Emissions of greenhouse gases in the European Union in 2015, transportation sector (Based on EEA, 2018)

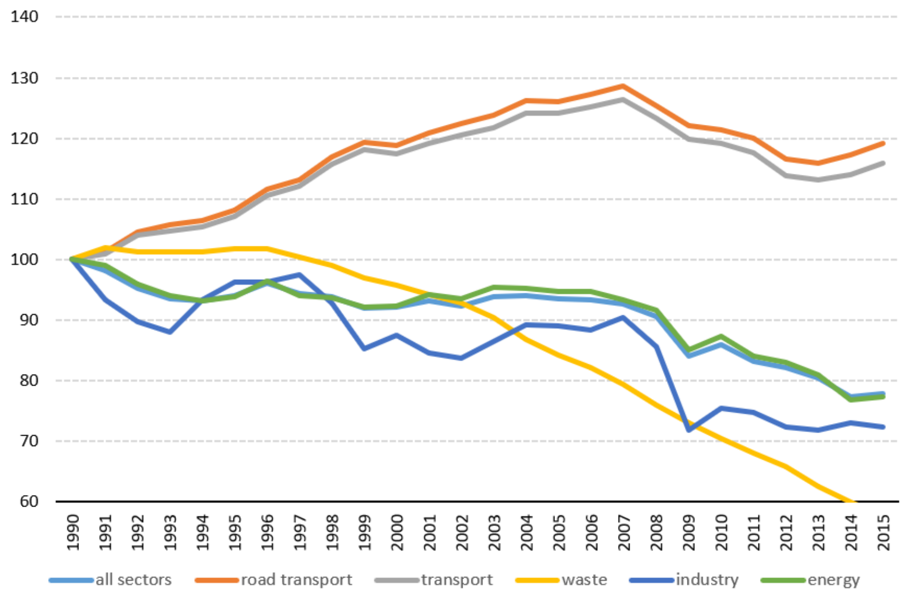

Fig. 3. Pollution emissions in the European Union (1990=100) (EEA, 2017)

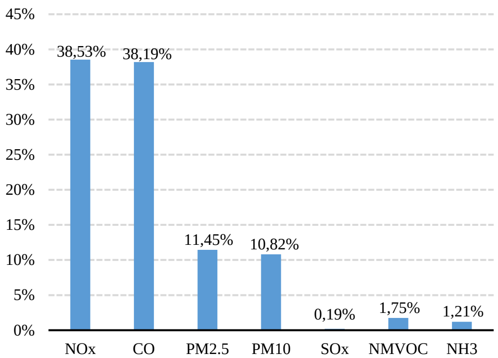

Fig. 4. The share of transportation pollution in the total emission of GHG in the European Union in 2015 (Eurostat, 2018).

WHO estimated as many as 23% of deaths (12 million each year) globally are related to environmental factors (Prüss-Ustün, 2016). Latest reports by the European Environment Agency (EEA) indicate that air pollution from all sources is responsible for 428 thousand premature deaths a year and 6.5 million Europeans are diagnosed with serious pulmonary and cardiovascular diseases (strokes, asthma, and bronchitis). In Poland, 47.3 thousand people a year die prematurely because of air pollution (EEA, 2016).

In consideration of the serious consequences of i.a. breathing polluted air and considerable acoustic nuisance encountered especially in cities, where it is necessary to solve as soon as possible the ecological problems resulting from mass transportation (Wilson, 2012), there have been numerous actions, both short- and long-term, implemented in the European Union for many years now aimed at reducing them (Jachimowski et al., 2018). Their goal is to achieve a more sustainable circular economy and decarbonization of the transportation system.

In light of the above, recent years have seen a substantial improvement in limiting the negative environmental impact of vehicles. The improvement concerns mainly the reduction of harmful emissions through the development of drive systems and use of alternative fuels, limited intake of natural resources and reduced waste through recycling of decommissioned vehicles, or reduced noise emissions.

According to the European Automobile Manufacturers' Association, car noise emissions have been reduced by 90% since 1970 (EEA, 2007). Eighty-five percent of vehicle components are recovered to be reused as spare parts, secondary raw materials, or in energy production. Additionally, road transportation recorded a larger reduction of emissions compared to other transportation sectors. A single car in 1970 produced as much pollution as 100 cars today (EEA, 2007). Gas and particulate emission limits in European standard Euro 6 are multiple times lesser than standards applicable before. Today, particulate filters can reduce diesel particulate emissions by over 99%. In 1995, 89% of new cars emitted more than 161 g of CO2 per km, and only 3%, 140 g/km or less. In 2008, only 42% of new cars emitted less than 140 g of CO2 per km and only 31%, more than 161 g/km. Due to strict regulations, vehicle exhaust gases are cleaner than the air in some urban environments (EEA, 2007).

Still, the whole effort is eradicated by the constant growth in car numbers.

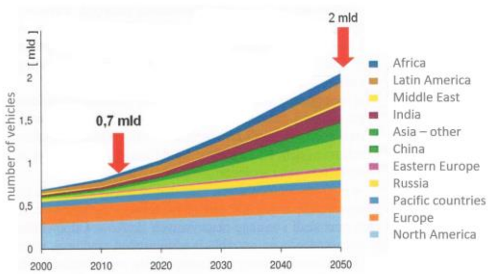

Fig. 5. Forecast global number of cars by 2050 (EEA, 2017)

Hence, as regards suprastructure, the European Commission has pointed out that the solution for the above-mentioned problems may be to increase the sales of alternatively driven vehicles, including those using battery only. According to the European Union policy, they are planned to make up half of the cars used in 2030 and after 2035, all sold cars will be fully electric according to Erich and Witteveen, (2017) (Fig. 6).

The share of battery electric cars in the automotive market in the European Union grows every year (Fig. 7) (the mid-term pace of change for 2010–2017 is $\overline{T}_G$=95%) and was 0.64% in 2017 (Fig. 8).

The automotive sector offers a broad variety of vehicles in terms of parameters and sources or energy: gasoline, diesel oil, biofuels, electrical energy, etc. Both electric motor and internal combustion vehicles have advantages and disadvantages. The analysis presented below is intended to determine the use of which type of vehicle is the best today. The discussion involved technical, economic, and environmental parameters and used a multi-criteria scoring method for the first time for such a type of analysis.

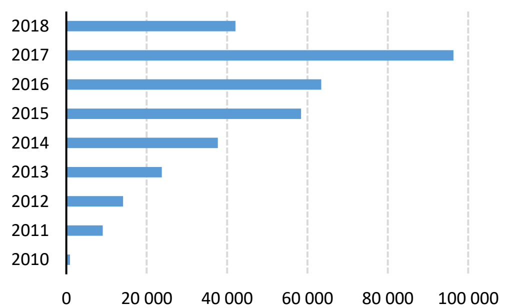

Fig. 7. The number of registrations of BEV (M1) in the European Union, 2010–18 (as of 06.2018) (EAFO, 2018; Sendek-Matysiak, 2018)

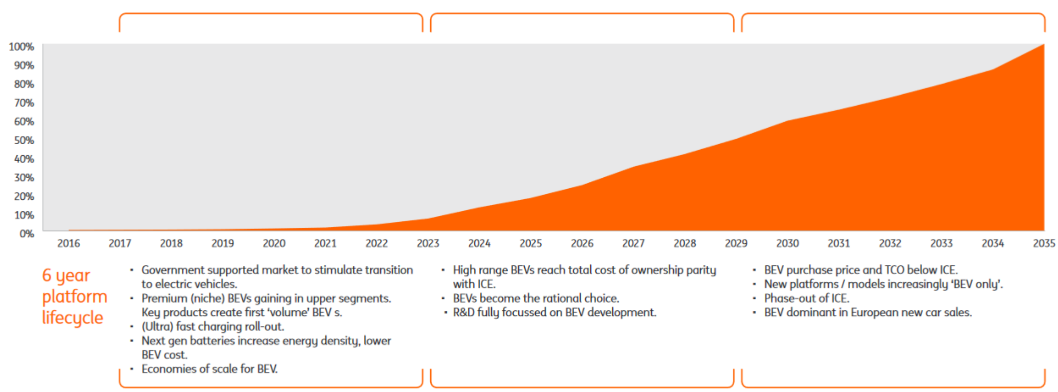

Fig. 6. Forecast share of electric cars in the European automotive market (Erich and Witteveen, 2017)

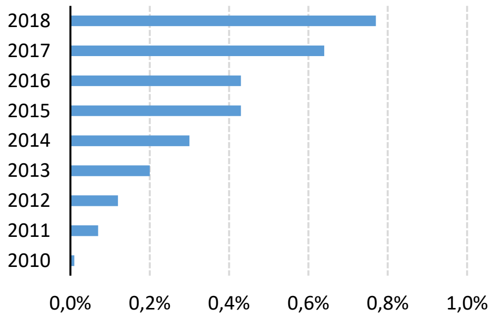

Fig. 8. The share of electric vehicles (M1) in the automotive market in the European Union, 2010–18 (as of 06.2018) (EAFO, 2018; Sendek-Matysiak, 2018)

2. Study material

The compared vehicles are a single model with different energy sources and drive systems in the same market segment (M1). They have the same or comparable total power, the same body type, the same type of drive (FWD) and gearbox (manual for conventional engines and automatic for electric motors). The variants were:
variant 1 – spark-ignition engine,
variant 2 – compression-ignition engine,
variant 3 – electric motor,
variant 4 – Plug-In hybrid drive.

Table 1 presents technical parameters, emission performance, cost of purchase, and other indices for the vehicles.

Table 1. Criteria score value [3, 15, 16, 26, 29, 30]

Costs	**Volkswagen Golf, 5-door**			
	Trendline 1.5 TSI ACT BlueMotion	**Trendline 1.6 TDI**	**e-Golf**	**GTE 1.4 TSI PHEV**
Curb weight [kg]	1,315	1,355	1,615	1,599
Load capacity [kg]	418–575	402–574	408–480	421–496
Total length [m]	4.36	4.26	4.27	4.27
Total width [m]	1.79	1.79	1.78	1.79
'Fuel' type	gasoline	diesel oil	electricity	gasoline/electricity
Average fuel consumption: gasoline [l] / diesel oil [l] / electrical energy [kWh] per 100 km	5.00	4.70	15.70	1.70
Maximum power [kW]	96	85	100	150
Maximum torque [Nm]	200	250	290	350
Maximum speed [km/h]	210	198	150	222
Acceleration 0–100 km/h [s]	9.10	10.20	9.60	7.60
Total range (combined) [km]	833.30	1,020.41	231.00	883.00
Cost of purchase [PLN]*	82,960	88,360	165,690	120,550
Cost of 100 km (combined) [PLN]*	25.55	24.02	18.68	8.69
Number of dealers, service workshops	97	97	3	3
Number of gas/charging stations (as of 12.2017)	6,643	6,643	142	6,785
Time necessary to refill fuel or charge batteries (charging with alternating current at charging stations) [min]	2	2	320	147
Additional privileges such as the use of bus lanes, purchase subsidy, etc. [0–2]	0	0	2	1
CO2 emission [g/km]	220	194	100	218
NOx+PMs emission [mg/km]	194	285	255	214
Noise emission at 100 km/h [dB]	64.3	65.3	60.5	64.9
NGC [0–100]**	40	37	22	32

* prices as of 11.10.2018
**NGC – an index encompassing CO, NOx, HCs, PM_{10}, SO_2, CO_2, CH_4, and N_2O emissions during the production of fuel, the vehicle, its use, and recycling/disposal (NGC, 2018)

3. Vehicle selection using a multi-criteria scoring method

The multi-criteria analysis involved the aggregation of normalized values of features for each vehicle variant using predetermined scoring criteria and ordering the variants from the best score. This method facilitates the determination of the unambiguously best solution and clustering of solutions into categories depending on the score.

It is also possible to score variants when scenarios or general objectives are defined such as technical, economic, or environmental with several criteria.

The core of each multi-criteria scoring method is to assign appropriate weight to individual criteria. In the case of objectives or scenarios, they need to be assigned weights as well. Note that the sum of weights may not exceed one or 100% if the importance of criteria is expressed as a percentage.

Details of the scoring method procedure can be found in (Jacyna et al., 2014; Jacyna and Wasiak, 2007).

The four variants (gasoline, diesel, hybrid, and electric car) were scored for environmental (objective 1), economic (objective 2), and technical (objective 3) criteria. The importance of the objectives c_k was determined in an expert discussion and the values are shown in Table 2. As assumed, the weights are between 0 and 1 and their sum is 1.

Each objective has appropriate partial scoring criteria; the first one has four, the second one has two, and the third one has five.

Table 2. Objectives and criteria of scoring and their weights

OBJECTIVE NAME (CRITERIA GROUP)	WEIGHT (c_f)
Environmental	0.6
Economic	0.3
Technical	0.1

The following weights were assigned to criteria, respectively:

- for the first objective:

$c_{1.1} = 0.3$, $c_{1.2} = 0.3$, $c_{1.3} = 0.2$, $c_{1.4} = 0.2$,

- for the second objective:

$c_{2.1} = 0.4$, $c_{2.2} = 0.6$,

- for the third objective:

$c_{3.1} = 0.3$, $c_{3.2} = 0.1$, $c_{3.3} = 0.3$, $c_{3.4} = 0.2$, $c_{3.5} = 0.1$.

Score values for individual variants in individual objectives and criteria are summarized in Table 3.

The scores were normalized to facilitate the comparison as per the procedure described above. The values of normalized scores are presented in Table 4.

Aggregated scores were determined by first multiplying weights of individual partial criteria by normalized scores for the criterion (Table 5). Next, the scores within objectives for each solution were aggregated and multiplied by weights of individual objectives.

In the next step, the values for each solution were aggregated.

Table 3. Score values for variants in individual objectives and criteria

Objective	Objective weight	Criterion [unit]	Criterion weight	Variants				Type of correlation
				1	2	3	4	
objective 1	0.6	CO2 emission [g/km]	0.3	220	194	100	218	negative correlation
		NOx+PMs emission [mg/km]	0.3	194	285	255	214	
		Noise level at 100 km/h [dB]	0.2	64.3	65.3	60.5	64.9	
		Environmental footprint, NGC [0–100]	0.2	40	37	22	32	
objective 2	0.3	Cost of purchase [PLN]	0.4	82,960	88,360	165,690	120,550	
		Cost of 100 km (combined) [PLN]	0.6	25.55	24.08	18.68	8.68	
objective 3	0.1	total range (combined) [km]	0.3	833.3	1,020.41	231	883	positive correlation
		Number of dealers, service workshops	0.1	97	97	3	3	
		Number of gas/charging stations	0.3	6,643	6,643	142	6,785	
		Time necessary to refill fuel or charge batteries (charging with alternating current at charging stations) [min]	0.2	2	2	320	147	negative correlation
		Additional privileges such as the use of bus lanes, purchase subsidy, etc. [0–2]	0.1	0	0	2	1	positive correlation

Table 4. Normalized scores

Objective	Objective weight	Criterion [unit]	Criterion weight	Variants				Type of correlation
				1	2	3	4	
objective 1	0.6	CO2 emission [g/km]	0.3	0.45	0.51	1.00	0.46	negative correlation
		NOx+PMs emission [mg/km]	0.3	1.00	0.68	0.76	0.91	
		Noise level at 100 km/h [dB]	0.2	0.94	0.93	1.00	0.93	
		Environmental footprint, NGC [0–100]	0.2	0.55	0.56	1.00	0.69	
objective 2	0.3	Cost of purchase [PLN]	0.4	1.00	0.94	0.50	0.69	
		Cost of 100 km (combined) [PLN]	0.6	0.34	0.36	0.46	1.00	
objective 3	0.1	total range (combined) [km]	0.3	0.82	1.00	0.23	0.86	positive correlation
		Number of dealers, service workshops	0.1	1.00	1.00	0.03	0.03	
		Number of gas/charging stations	0.3	0.98	0.98	0.02	1.00	
		Time necessary to refill fuel or charge batteries (charging with alternating current at charging stations) [min]	0.2	1.00	1.00	0.01	0.01	negative correlation
		Additional privileges such as the use of bus lanes, purchase subsidy, etc. [0–2]	0.1	0.00	0.00	1.00	0.50	positive correlation

Table 5. Scores after the multiplication of criterion weights and normalized scores

Objective	Objective weight	Criterion [unit]	Criterion weight	Variants				Type of correlation
				1	2	3	4	
objective 1	0.6	CO2 emission [g/km]	0.3	0.45	0.52	1.00	0.46	negative correlation
		NOx+PMs emission [mg/km]	0.3	1.00	0.68	0.76	0.91	
		Noise level at 100 km/h [dB]	0.2	0.94	0.93	1.00	0.93	
		Environmental footprint, NGC [0–100]	0.2	0.55	0.59	1.00	0.69	
objective 2	0.3	Cost of purchase [PLN]	0.4	1.00	0.94	0.50	0.69	
		Cost of 100 km (combined) [PLN]	0.6	0.34	0.36	0.46	1.00	
objective 3	0.1	total range (combined) [km]	0.3	0.82	1.00	0.23	0.87	positive correlation
		Number of dealers, service workshops	0.1	1.00	1.00	0.03	0.03	
		Number of gas/charging stations	0.3	0.98	0.98	0.02	1.00	
		Time necessary to refill fuel or charge batteries (charging with alternating current at charging stations) [min]	0.2	1.00	1.00	0.01	0.01	negative correlation
		Additional privileges such as the use of bus lanes, purchase subsidy, etc. [0–2]	0.1	0.00	0.00	1.00	0.50	positive correlation

Table 6. Synthetic score indices for individual variants

Objective	Variants			
	1	2	3	4
objective 1	0.44	0.40	0.56	0.44
objective 2	0.18	0.18	0.14	0.26
objective 3	0.08	0.09	0.02	0.06
W(v)	0.71	0.66	0.72	0.76

Based on the analysis of the data in Table 6, variant 4 (hybrid car) had the largest index value. This is the best variant with the largest value of the index if all criteria (environmental, economic, and technical) are considered together.

Additionally, the same procedure was applied to the data in Table 1 with emissions limited to the use period only. In such a case, the third variant, electric car had the largest index value (Table 7).

Table 7. Synthetic score indices for individual variants – case 2

Objective	Variants			
	1	2	3	4
objective 1	0.17	0.17	0.60	0.17
objective 2	0.18	0.18	0.14	0.26
objective 3	0.08	0.09	0.02	0.06
W(v)	0.43	0.43	0.76	0.49

4. Conclusions

The selection of a car focused on the type of drive is not easy, in particular when the assessment involves over a dozen criteria. The analysis confronted four cars, each with a different type of drive in terms of technical solutions, economic parameters, and environmental footprint. It was performed using multi-criteria scoring, used to select a vehicle for the first time here.

When vehicle emissions included those produced during the production of 'fuel', manufacture of the vehicle, its use, and recycling/disposal, the best variant was a hybrid car. When the emissions were limited to those generated during the use of the vehicle, the electric car turned out to be the best solution.

To conclude, the level of harmful substances released by the transportation sector can be reduced by increasing the share of electric cars in the automotive market subject to certain reservations such as the reduction of emissions produced during the production of batteries used in such cars. The multi-criteria scoring method used above is the right tool for such comparative analyses.

References

[1] AMBROZIAK, T., JACYNA, M., WASIAK, M., LEWCZUK, K., JACHIMOWSKI, R., KŁODOWSKI, M., PYZA, D., JACYNA-GOŁDA, I., MERKISZ GURANOWSKA, A., 2013. Identification and analysis of parameters for the areas of the highest harmful exhaust emissions in the model EMITRANSYS. *Journal of KONES*, 20(3), 9-20.

[2] AUTOCENTRUM, 2018. Autocentrum. Niezależny portal motoryzacyjny, Retrieved from URL: https://www.autocentrum.pl/dane-techniczne/volkswagen/golf/vii/e-golf-facelifting/silnik-elektryczny-electro-136km-od-2017/.

[3] AUTO-DECIBEL-DB, 2018. *The Car Interior Noise Level Comparison site - Auto innengeräusch vergleich*. Retrieved from URL: http://www.auto-decibel-db.com/index_kmh.html.

[4] BADYDA, A. J., 2010. Zagrożenia środowiskowe ze strony transportu. *Nauka*, 4, 115-125.

[5] CHARGEMAP, 2018. Retreived from URL: https://chargemap.com/about/stats/poland.

[6] EAFO, 2018. *European Alternative Fuels Observatory*. Retrieved from URL: http://www.eafo.eu/eu

[7] EC, 2011. *White Paper – Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*, COM(2011) 144 final, European Commission, Brussels.

[8] EEA, 2007. *Transport and environment, On the way to a new common transport policy*. Office for Official Publications of the European Communities: Copenhagen, European Environment Agency, 2007.

[9] EEA, 2014. *Monitoring CO_2 emissions from new passenger cars in the EU: summary of data for 2012*. European Environment Agency.

[10] EEA, 2016. *Signals 2016 - Towards clean and smart mobility*, European Environment Agency, Retrieved from URL: https://www.eea.europa.eu/publications/signals-2016.

[11] EEA, 2017. EEA greenhouse gas – data viewer.

[12] EEA, 2018. *European Environment Agency*, Retrieved from URL: www.eea.europa.eu./publicationc.

[13] ERICH, M., WITTEVEEN J., 2017. *Breakthrough of Electric Vehicle Threatens European Car Industry*, ING Report, ING Economics Department.

[14] EUROSTAT, 2018. *Eurostat database*, Retrieved from URL: http://ec.europa.eu/eurostat/data/database.

[15] JACHIMOWSKI, R., SZCZEPAŃSKI, E., KŁODAWSKI, M., MARKOWSKA, K., DĄBROWSKI, J., 2018. Selection of a container storage strategy at the rail-road intermodal terminal as a function of minimization of the energy expenditure of transshipment devices and CO2 Emissions. *Rocznik Ochrona Srodowiska*, 20, 965-988, 2018.

[16] JACYNA, M., MERKISZ, J., 2014. Proecological approach to modelling traffic organization in national transport system, *Archives of Transport*, 30(2), 31-41.

[17] JACYNA, M., MERKISZ-GURANOWSKA, A., JACYNA-GOŁDA, I., KŁODOWSKI, M., JACHIMOWSKI, R., 2014. *Kształtowanie systemów w wybranych obszarach transportu i logistyki*, Oficyna Wydawnicza Politechniki Warszawskiej, Warsaw.

[18] JACYNA, M., WASIAK, M., 2007. Metoda wielokryterialnej oceny wariantów realizacji inwestycji infrastrukturalnych w transporcie. *Prace Naukowe Politechniki Warszawskiej, Transport*, 63, 119-124.

[19] JACYNA, M., WASIAK, M., LEWCZUK, K., KAROŃ, G., 2017. Noise and environmental pollution from transport: decisive problems in developing ecologically efficient transport systems. *Journal of Vibroengineering*, 19(7), 5639-5655.

[20] JACYNA-GOŁDA, I., IZDEBSKI, M., PODVIEZKO, A., 2017. Assessment of efficiency of assignment of vehicles to tasks in supply chains: a case study of a municipal company, *Transport*, 32(3), 243-251, 2017.

[21] JACYNA-GOŁDA, I., IZDEBSKI, M., SZCZEPAŃSKI, E., GOŁDA, P., 2018. The assessment of supply chain effectiveness. *Archives of Transport*, 45(1), 43-52.

[22] ŁUKASIK, Z., KUŚMIŃSKA-FIJAŁKOWSKA, A., KOZYRA, J., 2017. Transport of dangerous goods by road from a european aspect, *Scientific Journal of Silesian University of Technology. Series Transport*, 95, 109-119.

[23] NGC, 2018. *Next green car*. Retrieved from URL: https://www.nextgreencar.com/emissions/ngc-rating/.

[24] POPHN, 2018. *Polish Organization of Oil Industry and Trade*. Retrieved from URL: http://www.popihn.pl/.

[25] PRÜSS-USTÜN, A., WOLF, J., CORVALÁN, C., BOS, R., NEIRA, M., 2016. *Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks*. Geneva: WHO, p. 22.

[26] SENDEK-MATYSIAK, E., 2018. *Analysis of the electromobility performance in Poland and proposed incentives for its development*. Retrieved from URL: https://ieeexplore.ieee.org/document/8373338, 2018.

[27] SENDEK-MATYSIAK, E., SZUMSKA, E., 2018. Infrastruktura ładowania jako jeden z elementów rozwoju elektromobilności w Polsce. *Prace Naukowe Politechniki Warszawskiej, Transport*, 121, 329-340.

[28] TRANSPORT PUBLICZNY, 2018. Retrieved from URL: http://www.transport-publiczny.pl/wiadomosci/warszawa-za-6080-za-nieczyszczen-odpowiada-transport-drogowy-54015.html.

[29] VW GOLF, 2018. Retrieved from URL: https://www.vwgolf.pl/dane-techniczne/vw-golf-mk7/.

[30] WASIAK, M., JACYNA, M., LEWCZUK, K., SZCZEPAŃSKI, E., 2017. The method for evaluation of efficiency of the concept of centrally managed distribution in cities. *Transport*, 32(4), 348-357.

[31] WILSON, L., 2012. *A 10 Step Guide to Understanding, Calculating and Reducing Your Carbon Footprint, „Shrink That Footprint”*, Retrieved from URL: http://shrinkthatfootprint.com/shrink-your-travel-footprint.