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DEVELOPMENT TRENDS OF THE AUTOMOTIVE MARKET AND ITS IMPACT ON THE ECOLOGIZATION OF UKRAINE

The article investigated the level of air pollution by vehicles. Using mathematical modeling, the relationship between the growth trend in the number of vehicles and an increase in harmful emissions is revealed. It was revealed that the production and sale of electric vehicles have a significant impact on greening. This is due to the efficiency, environmental friendliness and ease of use of electric vehicles. However, at the moment there are problems with the presence of an extensive network of electric power stations and the complexity of their maintenance. State support to eliminate these shortcomings and the popularization of electric vehicles in Ukraine will soon make this type of transport affordable and convenient to use. In today's realities of increasing the effectiveness of the automotive industry functioning, it is possible due to the creation of a competitive automobile industry in Ukraine, expanding the assortment, developing and introducing the concept of new high-quality domestic premium cars, using world experience in the development of the automotive industry. This applies primarily to eco-vehicles to ensure domestic demand and the future realization of the export prospects.

Key words: level of air pollution, ecologization, eco-vehicles, development of the automotive industry.

Костенюк Ю.Б., Крижанівська І.В.

ТЕНДЕНЦІЇ РОЗВИТКУ АВТОТРАНСПОРТНОГО РИНКУ ТА ЙОГО ВПЛИВ НА ЕКОЛОГІЗАЦІЮ УКРАЇНИ

В статті досліджено рівень забруднення атмосферного повітря автотранспортом. За допомогою математичного моделювання виявлений взаємозв’язок між тенденцією зростання кількості автотранспорту і збільшенням шкідливих викидів. Виявлено, що виробництво та реалізація електромобілів мають значний вплив на екологізацію. Це зумовлено економічністю, екологічністю та зручністю у використанні електромобілів. Проте, на даний момент існують проблеми з наявністю розгалуженої мережі станцій електричного живлення та складності їх обслуговування. Державна підтримка з усунення цих недоліків та популяризація електромобілів в Україні дозволять найближчим часом зробити цей вид транспорту доступним та зручним у користуванні. У сьогоднішніх реаліях підвищення ефективності функціонування автомобільної галузі можливе за рахунок створення в Україні конкурентоздатного легкового автомобілебудування, розширення асортименту, розробки та введення концепції нових високоякісних вітчизняних автівок преміум класу, залучення світового досвіду розвитку автомобільної галузі, в тому числі екомобілів для покриття внутрішнього попиту та у майбутньому реалізації перспективи експорту.

Ключові слова: рівень забруднення атмосферного повітря, екологізація, екомобілі, розвиток автомобільної галузі.

Костенюк Ю.Б., Крыжановская И.В.

ТЕНДЕНЦИИ РАЗВИТИЯ АВТОТРАНСПОРТНОГО РЫНКА И ЕГО ВЛИЯНИЕ НА ЭКОЛОГИЗАЦИЮ УКРАИНЫ

В статье исследован уровень загрязнения атмосферы автотранспортом. При помощи математического моделирования выявлена взаимосвязь между тенденцией роста количества автотранспорту и увеличением вредных выбросов. Выявлено, что производство и реализация электромобилей оказывают значительное влияние на экологизацию. Это обусловлено экономичностью, экологичностью и удобством в использовании электромобилей. Однако на данный момент существуют проблемы с наличием разветвленной сети станций электрического питания и сложности их обслуживания. Государственная поддержка по ликвидации этих недостатков и популяризация электромобилей в Украине позволят в ближайшем времени сделать этот вид транспорта доступным и удобным в использовании. В сегодняшних реалиях повышения эффективности функционирования автомобильной отрасли возможно за счет создания в Украине конкурентоспособного легкового автомобилестроения, расширения ассортимента, разработки и введения концепции новых высококачественных отечественных автомобилей премиум класса, использования мирового опыта развития автомобильной отрасли. Это касается, прежде всего, экомобилей для обеспечения внутреннего спроса и в будущем реализации перспективы экспорта.

Ключевые слова: уровень загрязнения атмосферы, экологизация, экомобили, развитие автомобильной отрасли.

Actuality. According to the World Health Organization, every year in the world, due to atmospheric pollution, prematurely dies on average 7 million people. About 92% of these cases occurred in countries with low and average GDP per capita [1].

The urgency of this work is to find a solution for controlling atmospheric air pollution by motor transport. Exhaust gases accumulate in the lower atmosphere, that is, harmful substances are in the human breathing zone. Therefore, road transport should be classified as the most dangerous sources of air pollution.

The purpose of the article. To investigate the level of atmospheric air pollution by motor transport and, with the help of mathematical modeling, to find out the interconnection between the trend of increasing the number of vehicles and the increase of harmful emissions.

Recent publications. The world tendency to switch to clean cars was discussed by Scottish scientists Victor Timmers and Peter A.J. Achten, a British researcher at the University of Hertfordshire Ranjeet Sokhi, Ozzi Zenera, Petrov S., Umryhina L., Klimchuk M., but left uncertain several issues, one of which is the problem.

The main material. An important source of atmospheric pollution are vehicles of all kinds. Automobile emissions - a mixture of about 200 substances, including aldehydes with a sharp smell and a strong irritant action, carcinogenic substances that can cause cancer and others.

At the end of the twentieth century in the world there were about 1 billion cars. Consequently, such a large amount of harmful effects on the ecosystem. Automobile transport mainly pollutes the atmosphere with three main channels:

- exhaust gases;
- crankcase gases;
- hydrocarbons due to the evaporation of fuel from the tank, carburetor and pipelines.

The average car in a year of mileage takes away from the atmosphere 4.35 tons of oxygen, emitting 3.25 tons of carbon dioxide, 0.53 kg of carbon monoxide, 0.093 tons of hydrocarbons, 0.027 tons of nitrogen oxides. As part of the exhaust gases of the car, the largest share in volume is carbon monoxide (0.5-10%), nitrogen oxides (up to 0.8%), unburned hydrocarbons (0.2-3%), aldehydes (up to 0 , 2%) and soot [2].

Due to the scientific and technological revolution and the urbanization of the planet, the environment is steadily deteriorating as a result of anthropogenic activity, which expose it to the ever-increasing influence of physical, chemical and biological loads. People are no longer able to adapt to these rapid and global changes. In addition, there was a problem of demographic explosion and limited natural resources and living space of the globe. Due to the catastrophic deterioration of the environment, the overall level of health of the population of Ukraine in recent years has fallen sharply. Genetic processes have broken down, the birth of children with different hereditary diseases has increased by 2-4 times. The life expectancy of people has decreased for 6 years, the index of primary disability has grown [2, 3].

For the construction of a mathematical model as an example, statistical data on the amount of emissions from motor vehicles and the frequency of respiratory diseases in each district of Vinnytsia oblast, which are given in the Statistical Yearbook of Vinnytsia region [4, 5], have been used. Taking into account that the areas of different districts of the Vinnytsia region differ significantly, instead of the absolute values of emissions, we will use relative, namely mass of emissions at 1 km^2. The corresponding initial data is summarized in table 1 and table 2.

Table 1

Mass of emissions at 1 km^2

№	District	2010	2011	2012	2013	2014	2015
1	Barskiy	1,67	1,77	2,22	2,31	2,19	2,27
2	Bershadskiy	2,39	2,55	3,05	3,37	3,29	3,09
3	Vinnitskiy	2,38	2,56	3,42	3,56	3,31	3,49
4	Gaysinskiy	2,29	2,39	3,22	3,08	2,75	2,85
5	Zhmerinskiy	0,73	0,73	1,4	1,57	1,44	1,48
6	Illinetskiy	1,85	1,86	2,38	2,51	2,25	2,34
7	Kalinvskiy	2,25	2,35	3,06	3,14	2,81	2,81
8	Kozyatinskiy	1,17	1,17	2,06	2,16	1,85	1,83
9	Krizhopilskiy	2,11	2,27	2,83	3,32	2,96	3,02
10	Lipovetskiy	1,45	1,47	2,05	2,29	2,05	2,09
11	Litinskiy	1,43	1,54	1,96	1,91	1,82	1,88
12	Mogiliv-Podilskiy	0,92	0,97	1,57	1,68	1,6	1,67
13	Murovanokurilovetskiy	0,91	0,96	1,41	1,49	1,47	1,44
14	Nemirivskiy	1,68	1,72	1,97	2,06	1,94	1,92
15	Orativskiy	1,17	1,19	1,76	1,85	1,71	1,78
16	Pischanskiy	1,15	1,25	1,64	1,69	1,61	1,62
17	Pogrebischenskiy	1,05	1,10	1,62	1,65	1,61	1,61
18	Teplitskiy	1,31	1,43	1,94	2,07	1,89	1,94
19	Tivrivskiy	1,72	1,87	2,36	2,59	2,32	2,38
20	Tomashpilskiy	2,3	2,26	2,9	2,86	2,78	2,78
21	Trostyanetskiy	1,59	1,69	2,2	2,28	2,17	2,25
22	Tulchinskiy	2,73	2,75	2,55	2,65	2,47	2,57
23	Hmilnitskiy	0,62	0,66	1,56	1,7	1,53	1,65
24	Chernivetskiy	0,97	1,02	1,92	1,92	1,84	2
25	Chechelnitskiy	0,98	1,06	1,34	1,4	1,34	1,39
26	Shargorodskiy	1,68	1,71	2,58	2,59	2,33	2,46

Source [4, 5]

Sample data from table 1 and 2 write as follows:

$$\sum(x_1^t, y_1^t),\ i = \overline{1,27},\ t = \overline{2010,2015},$$

wherein (x_1^t, y_1^t) - the density of emissions from vehicles and the frequency of respiratory diseases; in the *i* district in *t* year.

The problem is as follows: to find the regression model y f = (x), for which the mean quadratic random sampling (2) is minimal. By typical regression analysis linear and quadratic models with large discrepancies were obtained RMSE = 812.1 and RMSE = 811.7. The inconsistencies are almost the same, so there is no point in raising the polynomial order.

By the distribution of experimental data, heuristic bundles of 2 clusters with visually notable correlations between the density of emissions and the incidence of diseases were detected. Accordingly, from 27 districts formed 2 groups (A and B), each of which has its own regression dependence. The group includes all areas for which the average frequency of diseases to the density of emissions in 2010-2015 is less than a certain threshold T. All other areas will form a group.

Table 2

Frequency of respiratory diseases (cases per 10 thousand people)

№	District	2010	2011	2012	2013	2014	2015
1	Barskiy	2800	2830	3100	3130	3100	2992
2	Bershadskiy	4000	4050	3975	3975	3880	3976
3	Vinnitskiy	4735	4781	4786	4780	4720	4760,4
4	Gaysinskiy	4700	4750	4750	4700	5050	4790
5	Zhmerinskiy	3500	3550	3075	2850	3065	3208
6	Illinetskiy	2800	2950	3100	3150	5750	3190
7	Kalinvskiy	5800	6000	5750	5700	4750	5800
8	Kozyatinskiy	4400	4350	4400	4450	4100	4470
9	Krizhopilskiy	3950	4000	4050	4075	4900	4035
10	Lipovetskiy	5000	5050	5050	4850	5900	4970
11	Litinskiy	5700	5750	5850	5850	3930	5810
12	Mogiliv-Podilskiy	3650	3750	3950	3750	4000	3806
13	Murovanokurilovetskiy	3900	4000	3900	4000	4000	3960
14	Nemirivskiy	4000	4100	4250	4400	4425	4235
15	Orativskiy	3900	4000	4075	4650	5200	4365
16	Pischanskiy	4000	4100	4150	4850	4800	4380
17	Pogrebischenskiy	4250	4300	4800	4300	4700	4470
18	Teplitskiy	4900	5000	5750	4950	5850	5290
19	Tivrivskiy	3400	3500	3750	3700	3750	3620
20	Tomashpilskiy	3850	3900	4050	4450	4500	4150
21	Trostyanetskiy	3400	3500	4000	4000	4650	3910
22	Tulchinskiy	3450	3900	3750	4000	4050	3770
23	Hmilnitskiy	4950	5000	5150	4450	4800	4870
24	Chernivetskiy	3625	3800	3800	3800	4500	3905
25	Chechelnitskiy	2100	2300	2400	2600	2900	2460
26	Shargorodskiy	5000	5200	5250	5000	5000	5090
27	Yampilskiy	3000	3200	3900	3500	3850	3490

Source [4,5]

Completed simulation of the system using Mathcad. Mathematically, this partition is written as follows:

$$\begin{cases} A = \left\{ i: \frac{1}{6} \sum_{t=2010}^{2015} \frac{y_i^t}{x_i^t} < T, i = \overline{1,27} \right. \\ B = \left\{ i: \frac{1}{6} \sum_{t=2010}^{2015} \frac{y_i^t}{x_i^t} \geq T, i = \overline{1,27} \right. \end{cases}$$

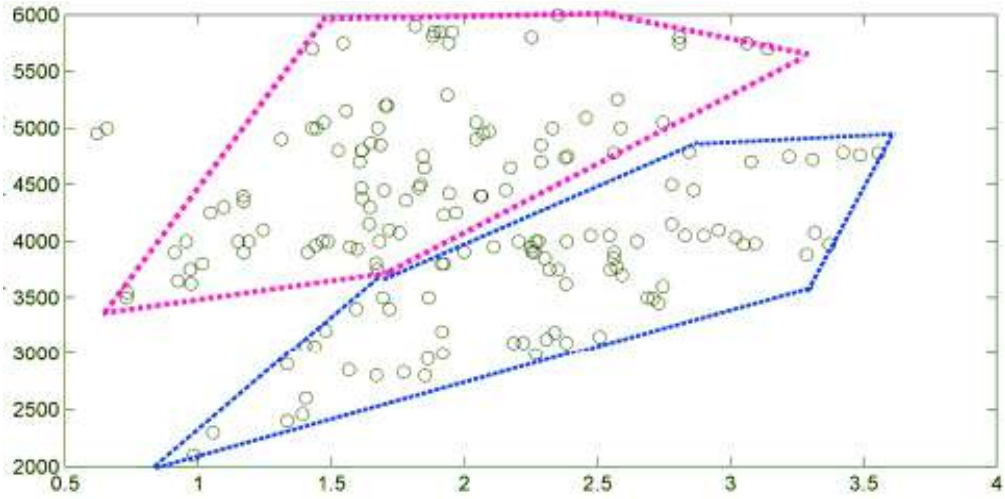

Figure 1 - Density of emissions from motor vehicles

After that, linear regression models are constructed for each group. The threshold T is selected so that the inconsistency across the entire sample (2) is minimal. As a result of this task, the districts are divided into the following groups:

A={1, 2, 3, 4, 6, 9, 19, 20, 21, 22, 25, 27} and

B={5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 23, 24, 26}.

The regression models are:

- for group A – y = + 1593,3 897x ;
- for group B – y = + 3224,3 801,7x .

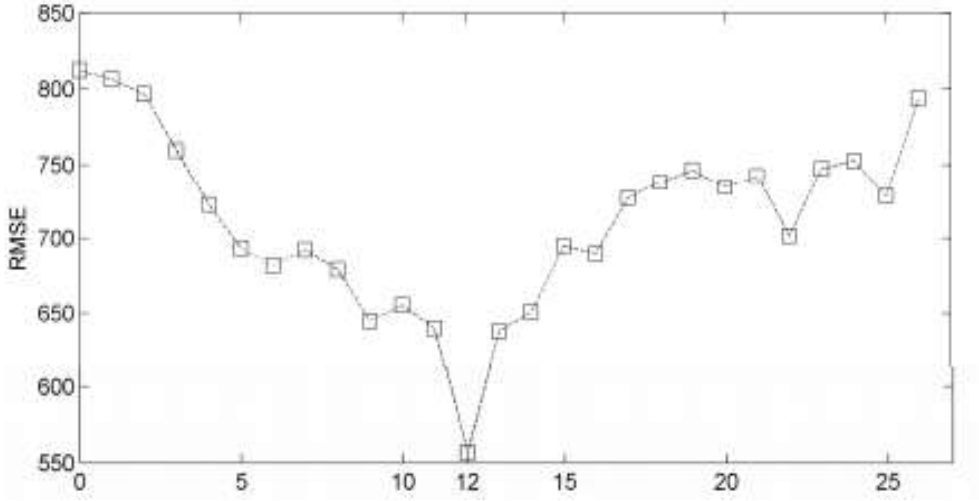

Figure 2 - Number of districts in group A

The results of the simulation coincide well with the experimental data with non-binding. From Fig. 4 it follows that for both groups of regions the increase in the density of emissions from motor vehicles almost equally affects the growth of respiratory diseases. But in the areas of the group, approximately 2 times the background level of such diseases, which can be determined by the regression models obtained in the absence of pollution from motor vehicles.

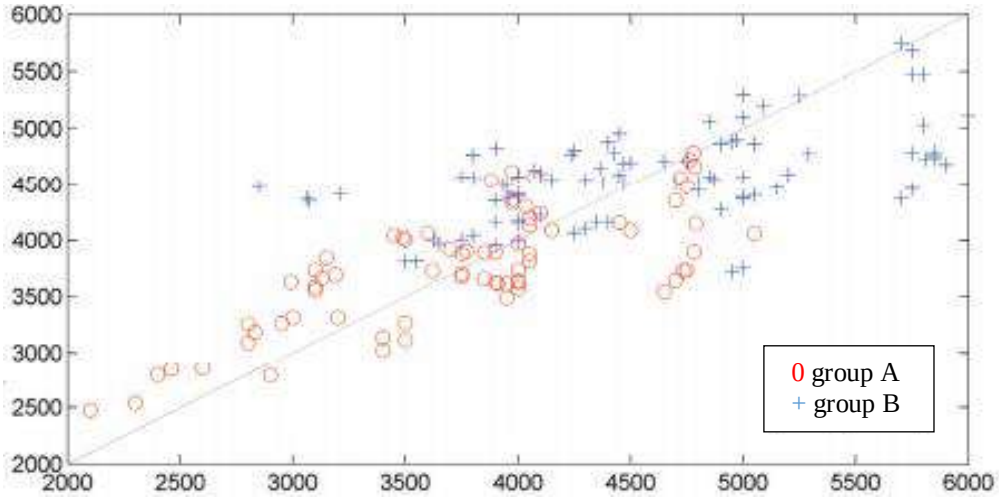

Figure 3 - Comparison of data and modeling results

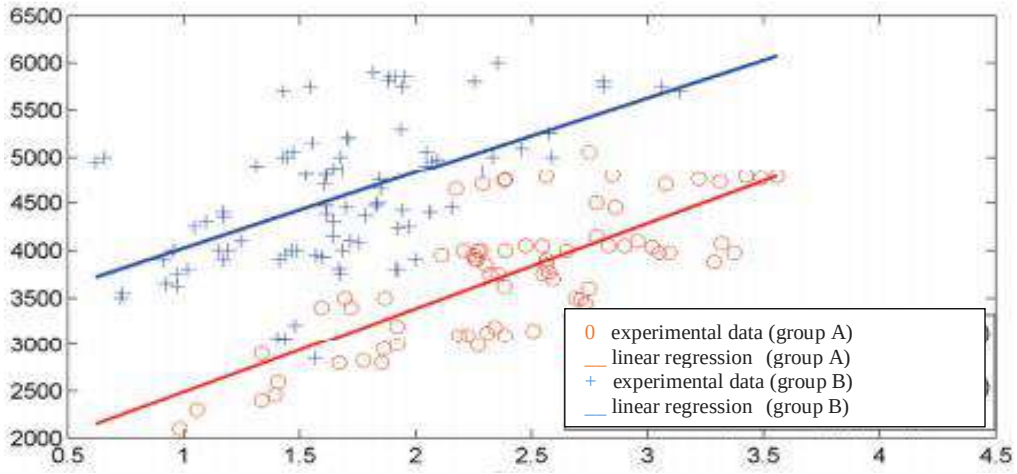

Figure 4 - Theoretical and experimental investigated dependencies

Due to the constant increase in the number of cars, the number of pollutants that reach the atmosphere causes various diseases in humans increases. There is a direct interconnection between the density of emissions from vehicles and the frequency of respiratory diseases.

According to the State Statistics Service of Ukraine, in 2017 emissions of pollutants to the atmosphere from stationary and mobile sources amounted to 2584.9 thousand tons. In 2017, 124.2 million tons of carbon dioxide, which has an impact on climate change, was thrown into the atmosphere, which is 17.3% below that of 2016. From mobile sources, in 2015, 1663.9 thousand tons of pollutants came into the air, which is 4673.3 thousand tons or 16.8% less than in 2014 (statistical indicators for the period 2016-2017 on the site of the State Statistics Service

of Ukraine is absent). The most polluted substances were emitted by road transport 1475.2 thousand tons (88.7% of the total volume), including 1075.9 thousand tons of road transport (64.7%). Emissions from production equipment amounted to 144.7 thousand tons (8.7%), rail transport - 29.7 thousand tons (1.8%), aviation - 8.5 thousand tons (0.5%), water - 5,8 thousand tons (0,3%) [12].

The largest emissions from stationary sources of pollution in 2017 were observed in the Donetsk region of 657.3 thousand tons or 30.4% of the total volume of the country, Dnipropetrovsk region - 657.3 thousand tons or 25.4% and Ivano-Frankivsk region - 198,3 thousand tons or 7.7%. Compared to the previous year, the increase in atmospheric emissions was noted in 13 regions of the country, namely: Vinnitsa (by 30%), Ternopil (by 16.8%), Odessa (by 12.2%), Zhytomyr region (by 11.5%), Volyn (9,9%), Chernivtsi (8,5%), Zaporozhye (8,3%), Lviv (5,8%), Rivne (5%), Kirovograd (3, 3%), Sumy (by 2.6%), Nikolaev (by 2.1%), Ivano-Frankivsk (by 0.8%). The leader among the indicators of the rate of increase of atmospheric emissions is Kyiv with an index of 32.5% to the indicators in 2016 [12].

For each inhabitant of Ukraine in 2017 there were 60.8 kg of pollutant emissions. Territorially, for every square kilometer of the territory of the country there were 4.5 tons of polluting air substances [12].

According to the statistics of the International Transport Forum, the shipping shipping companies provide transportation to 90% of world trade, while the share of maritime transport accounts for only 2-3% of the total volume of greenhouse gases in the atmosphere. To compare the emissions of a bulk carrier in grams of CO_2 per tone-kilometer, on average, it is 10 times less than in a truck with a total weight of 40 tons. At the same time, international organizations recognize that greenhouse gas emissions in the maritime transport sector cannot be tied to a particular country, but should be governed by joint efforts and international agreements under the leadership of the International Maritime Organization (IMO), making this link of transport an ideal alternative to road transport [12].

The level of transport safety, the amount of energy consumption and the impact on the environment in Ukraine do not meet current requirements. Over the past decades, the world has witnessed a rapid increase in the number of vehicles and increased traffic, which leads to an increase in the number of transport events and their negative consequences.

In the period from 2011 to 2016, 26.7 thousand people died in traffic accidents in Ukraine, of which 43.7% were pedestrians and cyclists. According to the World Bank, annual losses in traffic accidents in Ukraine are about $ 4 billion to $ 5 billion. Thus, in 2016, nearly 3,400 people died on Ukrainian roads, 33.6 thousand were injured. 90-95% of pollutant emissions into the air of cities, in places of accumulation of people falls on road transport. The EU transport policy set the target of halving the use of cars on traditional fuels in cities by 2030 and completely abandoning them by 2050 [9].

In Ukraine, the production of passenger cars reached peak in 2008 and amounted to 402 thousand units. At the same time, a record rate of new car sales was recorded. The Ukrainian car market ranked 7th in Europe with an index of 623 thousand new cars [7].

Already in 2009, the production of passenger cars has decreased by 5 times, to 65.7 thousand units, or 1.4 cars per capita. The fall in volumes of production is due to the crisis in the world economy, as well as the depleted demand by the population in the car and the lack of cheap credit resources. Also, due to the reduction of the import duty from 25% to 10%, after

the accession of Ukraine to the WTO, the structure of filling the domestic market and a significant imbalance towards imports took place [7].

Given the electric vehicle boom in Europe, Ukraine is given a unique chance to prove itself and become one of the leaders in the production of electric transport. The strategy for success is simple - we need to create the conditions for European experience, to attract world automotive companies, who are in need of expansion of production capacities.

In Ukraine, there are already examples of opening and successful work of European companies. For example, in the Zakarpatskiy region, the company "Eurocar" thanks to the involvement of Polish investments, the production of cars of the VW Group (Skoda, Volkswagen, Seat) has been established.

Among the Ukrainian scientists and manufacturers there are already attempts to organize the production of electric cars and spare parts for them, as well as processing cars with gasoline engines on electric vehicles. In particular, the Kiev plant of trailers "Titan", known for its products not only in Ukraine, but also abroad, will deal with the processing of cars with internal combustion engines on electric vehicles. Today the plant has been engaged in the processing of gasoline cars of well-known brands in electric vehicles [9]. Also on the Ukrainian market was the Hong Kong company BIO Auto, which specializes in the manufacture of electric vehicles, with its models EVA [10]. Electric cars have already gained their popularity in the European Union due to the following benefits [11]:

- efficiency (90-95%) several times higher than the coefficient of efficiency of the internal combustion engine (22-42%);
- the electric car does not require such environmentally harmful chemicals as antifreeze, engine oil, no exhaust;
- the use of the electric motor helps to simplify the design of the car;
- the electric motor causes less noise;
- the electric car will not explode and will not burn in the event of an accident;
- it can be charged from a regular home network, although it will be 5-10 times longer than that of a special charger;
- it can stop the car by an electric motor, which makes it unnecessary to have a traditional brake.

With all these advantages, electric vehicles are still not often found on Ukrainian roads. The market of electric cars depends on the economic situation in the country. This product exceeds the traditional value, but in the long run it can give a significant effect to users, especially considering the cost of gasoline. But there is doubt about the readiness of Ukrainian road infrastructure for electric vehicles. In Ukraine today there are about 50 gas stations for electric cars, of which about 30 are in Kiev. Compared to hundreds of conventional gas stations, this is definitely a small amount. In addition, the use of electric vehicles has some disadvantages [11]:

- significant costs of battery charge at low temperatures;
- problem of utilization of batteries;
- the problem of spare parts;
- danger to pedestrians in connection with the quiet operation of an electric vehicle.

However, despite the drawbacks, the massive use of electric vehicles should improve the ecological situation in the country, reduce the level of illness among the population and provide

the state with additional resources that will be saved and able to be used for development and satisfaction of other needs of the population.

A survey was conducted to assess the readiness of the domestic consumer for the introduction of electric vehicles. The survey was attended by drivers, executives of transport companies, science and education staff of 50 people. According to the polls, fuel economy is considered to be the biggest advantage of an electric vehicle (93% of respondents). Exploitation of an electric vehicle is not very convenient under current conditions, 32% of respondents noted this factor. The survey found that most drivers use cars with internal combustion engines (99%) and either plan to install gas cylinders (15%) or have already installed them (44%). Only 3% of drivers are ready to replace the gasoline engine with an electric. The main reason that drivers have called is the need to retrofit the vehicle when installing an electric motor (91%) and the high cost of engine replacement (85%). Thus, if replacement of the engine does not require an additional re-equipment of the car, more drivers agreed to such a replacement. It was found that 75% in the presence of developed infrastructure, when choosing to buy an electric car, because it is more economical and efficient in operation.

Conclusions. From the conducted research it can be concluded that the production and sale of electric vehicles are relevant, since such products have a potential demand from consumers. This is due to factors such as its economy, eco-friendliness and ease of use. However, at the moment there are problems with the presence of an extensive network of power stations and complexity in servicing. State support for eliminating these shortcomings and popularization of electric vehicles in Ukraine will allow this type of transport to be made available and easy to use in the near future.

In today's realities, improving the efficiency of the automotive industry is possible due to the creation of competitive automotive construction in Ukraine, the expansion of the range, the development and introduction of the concept of new high-quality domestic cars of premium class, the involvement of world-wide experience in the automotive industry, including eco-cars to cover domestic demand and realization of the export perspective in the future. It is also important to conduct marketing researches of consumer behavior, to apply innovative marketing tools of influence on consumer behavior, to improve marketing strategies of Ukrainian automobile construction companies in order to attract and increase consumer demand. These measures will contribute to the growth of Ukraine's automotive industry and the volume of production in this sector.

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