Vasyl Faifura, Oleksandr Bondar, Vasyl Faifura. Ecological-spatial aspects of pollution in the region by elastoplastic micromasses. *Економічний дискурс*. 2024. Випуск 1-2. С. 44-51.
DOI: https://doi.org/10.36742/2410-0919-2024-1-5

УДК 332.1; 504
JEL Classification Q20; Q30

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ECOLOGICAL-SPATIAL ASPECTS OF POLLUTION IN THE REGION BY ELASTOPLASTIC MICROMASSES

Abstract
Introduction. *The ecological and spatial aspects of the pollution of the Ternopil region by elastoplastic micromasses, which are formed as a result of the operation of motor transport, have been considered. The purpose of the article is to study the spatial aspects of the formation and spread of microelastomers on the highways of the region.*
Methods. *The methods of analysis and synthesis, as well as systematic generalization, were used in preparing the scientific publication.*
Results. *The main linear sources of environmental pollution by elastomers have been identified, and the characteristics of the processes of their formation and migration within the region due to the development of the transport infrastructure and the impact of settlement processes have been presented. Calculations of the volumes of microplastic masses formed on different motorways have been carried out.*
Discussion. *Taking into account a number of environmental parameters will make it possible to build models of the spread of pollution by microplastic masses in the region, visualize them on maps and make proposals for reducing the negative impact of elastomer pollution on the environment and public health.*
Keywords: *elastomers; microplastics; elastoplastic micromasses; pollution; motor transport; highways; environment; region.*

Introduction.

Over the past decade, increasing attention has been paid to the issue of environmental pollution by microplastic masses. The perception of the threat has undergone a transformation from solely evaluating the physical volumes of plastic production, the accumulation of plastic pollutants, and the lack of effective mechanisms and technologies for recycling such large quantities of plastic waste, to understanding the specific forms of microplastic accumulation.

On the one hand, plastic production has reached the third-largest volume, after metals and concrete. On the other hand, the named materials are natural, and their presence in the environment is ultimately predictable. Plastics, however, are artificial and unnatural to the environment, so the environment cannot integrate them into its natural material cycles in the future.

Despite the resistance of plastics to external environmental factors, they break down into microparticles. This represents a specific and unique form of environmental pollution by plastic.

Firstly, a significant portion of plastics, due to physical, chemical, and mechanical impacts, breaks down into particles invisible to the naked eye. However, the pollution is not caused by large items like bags, plastic containers, or the casings of household or other equipment, but rather by polymeric masses. The invisibility of one kilogram of HDPE or LDPE means that this same kilogram of substances remains in the environment, just in a form invisible to us. This reduces awareness of the problem and encourages manufacturers to take shortcuts – often adding substances to plastic compositions that stimulate the breakdown of polymer chains to the molecular level.

Secondly, in this form, plastic masses migrate more easily and are absorbed by biological organisms, and the consequences of this are still highly unpredictable.

A significant portion of plastics enters the environment as a result of the use of motor transport. For instance, vehicle tires are composed of approximately one-quarter polymers. Despite their resistance to wear, the use of car tires leads to their rapid abrasion and the release of micro-rubber particles into the air and water. Although the dominant volumes of microplastics are observed in marine and oceanic waters, their presence in the air takes a different path – only about 11% of atmospheric microplastic comes from marine spray, while around 84% originates from road dust [2]. Soil pollution is also significant – micro-rubber particles worn off tires accumulate in the soils along roadsides, where they reach concentrations of 10.0 g/kg of soil.

Analysis of recent research and publications.

The issue of the entry of micro-rubber particles and other micro-pollutants into roadside ecosystems has been the focus of many researchers. General issues related to transport ecology are outlined in sources [4; 9]. Several authors emphasize the particular environmental dangers posed by urban transport systems [12]. N. Kharitonova and V. Khrutba highlight that the wear and tear of car tires is the largest source of micro-pollutants resulting from the interaction between roads and vehicles, while the volume of microparticles from the wear of road markings, brakes, and asphalt concrete is estimated to be ten times less [11, p. 252]. Studies also address the determination of pollutant emissions considering the movement patterns of traffic flows [5], the impact of motor vehicles on the transformation of roadside ecosystems [1; 6], and specific works deal directly with the pollution of territories by microplastic masses. In this article, we will focus on highlighting the spatial aspects of environmental pollution in the region in the context of the entry of microplastic masses during the operation of motor vehicles.

Purpose.

The purpose of the article is to study the regional aspects of the formation of microplastic masses as a result of motor vehicle operation.

Methods.

The methods of analysis and synthesis, as well as systematic generalization, were used in preparing the scientific publication.

Results.

Each kilometer driven by an ordinary car is accompanied by the formation of approximately a trillion micro-particles of tire dust. In some cases, the level of pollution from this dust is so high that its harmfulness is almost equal to that of vehicle exhaust gases. Research shows that the volume of PM2.5 and PM10 micro-particles, which arise due to tire, brake pad, and disc wear, can even exceed the emissions from the exhaust pipes of the same vehicles [8].

There are three main types of tire tread wear. The first type, fatigue wear, occurs due to the destruction of the top layer of rubber under the influence of multiple deformations caused by contact with road surface irregularities. The second type, abrasive wear, occurs due to the increase in temperature during friction between two surfaces, leading to cracks and breaks in the tread. This can happen due to sudden and prolonged braking or acceleration of the vehicle, as well as at high speeds on turns. The third type of wear, known as «scuffing», manifests itself in the formation of a system of parallel ridges and valleys on the tread, perpendicular to the direction of travel.

Tire wear usually occurs through a mixed type, where these three types of wear combine. The intensity of wear is influenced by factors such as tire construction, tread pattern, rubber composition, driving speed, the technical condition of the car, wheel load, tire pressure, air and tire temperature, as well as the style and skill of driving [9, p. 108-109].

Based on the places where elastoplastic micromasses are formed, two main spatial types can be distinguished, which differ in the predominant mechanisms of pollutant formation:

Urban ecosystems – the formation of elastoplastic micromasses is characterized by high concentration (large volumes in small areas) due to frequent starts and stops, often abrupt, when driving on city asphalt;

Highways (factors – predominantly wear with the formation of a large amount of elastoplastic micromasses, and high-speed driving sharply accelerates tire wear).

In the speed range from 0 to 40 km/h, the main cause of tire wear is acceleration. The optimal driving mode is 41-80 km/h (elastomer release is minimal and occurs mainly due to the mechanical impact of road surface irregularities and light braking). The most rational driving mode is 81-110 km/h (the reasons are the same, but tire material wear increases by 10-20%), and starting at speeds of 120 km/h and above, the tire tread wear coefficient increases by 25-30% [13].

The transport-related component of microplastic pollution in the Ternopil region is one of the most significant. In general, motor transport is the most important ecological aspect of impact on the regional environment. The basis of the transport complex is motor transport, and the region is covered by a dense network of highways. The region is a leader in the number of paved roads per 1000 m^2. Out of 5000.1 kilometers of all roads, 99.5% have a hard surface, amounting to 4976.2 km. The road network is quite dense. The most important highways run from north to south and from west to east.

The length of international highways within the region is 307.1 km, including:

- M-19 «Domanove – Kovel – Chernivtsi – Terebleche» with a length of 200.7 km;
- M-12 «Stryi – Ternopil – Kirovohrad – Znamianka» with a length of 106.4 km.

Highways connecting Ukraine with European Union countries pass through the region. The system of highways, their functional purpose, and the transport convenience of the area are shown in Figure 1.

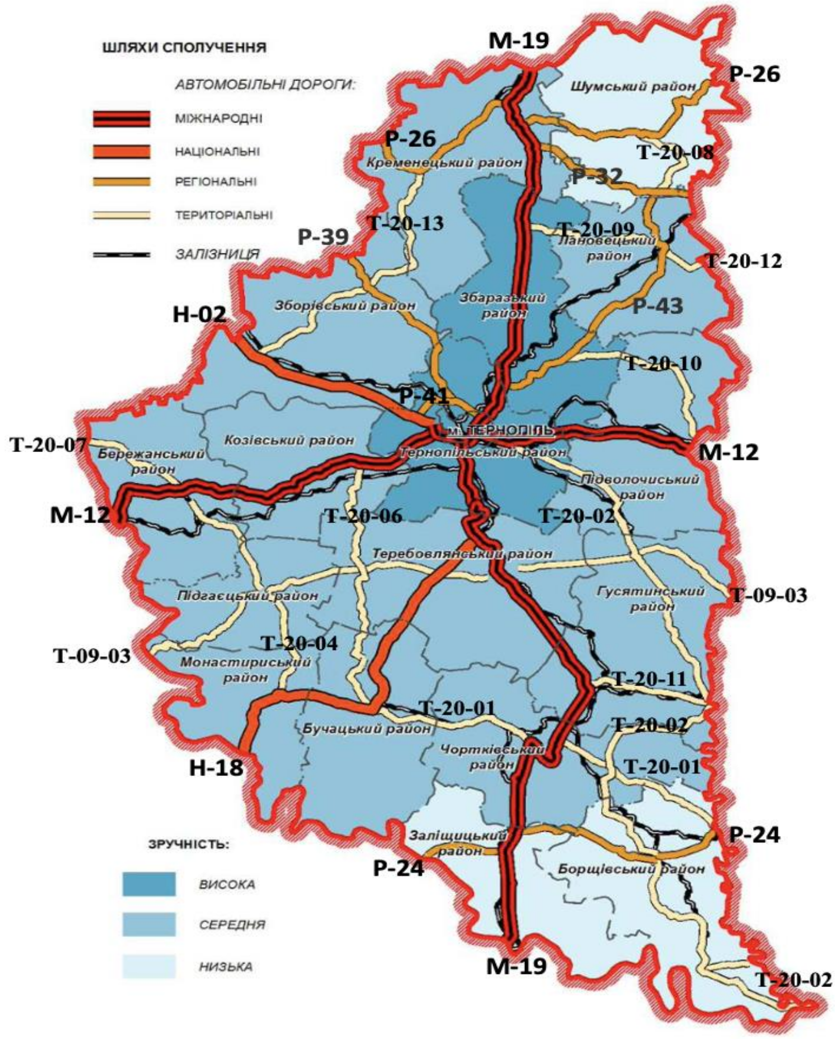

Fig. 1. Transportation routes and transport accessibility of the region's territories*
**Source: according to data [7, p. 132]*

Our further research into the spread of microelastomers in the environment is based on the intensity of traffic flows on the main highways of the region and the norms of tire wear over the relevant period. Traffic intensity is determined by the number of vehicles passing along a highway over a certain period. It is necessary to distinguish between specific and adjusted traffic intensity. The former describes the intensity per one lane of the road. For our calculations, we operate with the adjusted intensity, which represents the combined intensity of different types of vehicles, taking into account the relevant conversion coefficients for these types. The traffic flow is mixed, and considering each vehicle type, their groups, seasonality, and the surface area of roads individually is both very difficult and complicates the calculations without adding precision. Therefore, we use the number of vehicles, converted into the equivalent of a standard passenger car using conversion coefficients (Table 1), as an indicator of intensity.

Table 1. Conversion coefficients for vehicles to passenger car equivalents*

Vehicle Type	Conversion Coefficient	Vehicle Type	Conversion Coefficient
Motorcycle without sidecar and moped	0,5	Road train with payload capacity, tons: - up to 12	3,5
Motorcycle with sidecar	0,75	- from 12 to 20	4,0
Passenger car	1,0	- from 20 to 30	5,0
Truck with payload capacity, tons: - up tp 1	1,0	over 30	6,0
- from 1 to 2	1,5	Wheeled tractor with trailer capacity, tons, - up to 10	3,5
- from 2 to 6	2,0	- over 10	5,0
- from 6 to 8	2,5	Bus	3,0
- from 8 to 14	3,0	Long-base bus	5,0
- over 14	3,5		

**Source: according to the requirements [3].*

The adjusted traffic intensity, relative to a conventional passenger car, allows for calculating the number of different types of vehicles moving along the roadway. It shows how many passenger cars would be required to replace a particular type of vehicle in order to exert the same load on the road surface and cause the same level of environmental damage.

Due to the lack of comprehensive statistical data regarding the traffic intensity on the region's roads, it became necessary to use a combination of various sources for this indicator. The assessment of traffic intensity on the roads of the Ternopil region was based on the use of available statistical data, materials from strategic planning documents for the development of the region, comparison of the status of individual roads with traffic intensity indicators for roads of the same status in neighboring regions, as well as personal observations of traffic flows.

In assessing the mass fractions of elastomers that enter the environment, we proceeded from the fact that modern automobile tires are composed of approximately 41% various types of rubber [14]. If we calculate the percentage of other components in modern summer tires from the Continental brand, the breakdown is as follows: fillers (carbon black, silicon dioxide, carbon, chalk, etc.) – 30%, reinforcing materials (steel, polyester, viscose, nylon) – 15%, plasticizers (oils and resins) – 6%, vulcanization chemicals (sulfur, zinc oxide, etc.) – 6%, anti-aging agents (components to slow rubber aging) and other chemicals – 2%.

For more accurate calculations, it is necessary to calculate the mass fractions of the components of the rubber mixture (tread rubber) without reinforcing materials (steel), keeping in mind that the same rubber mixture is used for all parts of the tire. In this case, the composition looks slightly different: rubber (natural and synthetic) – 45.6%, fillers (carbon black, silicon dioxide, carbon, chalk, etc.) – 33.3%, polyester, viscose, nylon – 5.6%, plasticizers (oils and resins) – 6.7%, vulcanization chemicals (sulfur, zinc oxide, etc.) – 6.7%, anti-aging additives – 2.1%. Accordingly, elastomers account for 45.6% of the tread mixture, and in a complete automobile tire, the polymer content reaches 45.6% + 5.6% = 51.2% [10].

The calculated traffic intensity on the roads of the Ternopil region (vehicles per day), the daily mass of worn tire material (kg), the daily mass of worn elastomer, which accounts for 45.6% of the tread rubber (kg), and the daily mass of worn elastomer per kilometer (kg per 1 km) are shown in Table 2.

Table 2. Daily mass of worn elastomer per 1 kilometer of traveled road in the Ternopil region*

	Section	Traffic intensity, vehicles/day	Daily mass of worn tire material, kg	Daily mass of worn elastomer (45.6%), kg	Section length, km	Daily mass of worn elastomer per 1 km, kg/km
International Highways						
M-12	Striy – Ternopil – Kirovohrad – Znamianka				106,4	
	Pidvyisoke – Berezhany – Ternopil	10200	19,788	9,023	66,3	0,13609
	Ternopil – Pidvolochysk	19800	38,412	17,516	40,1	0,43681
M-19	Domanove – Kovel – Ternopil – Chernivtsi – Terebleche				200,7	
	Shepetyn – Kremenets – Ternopil	12380	24,017	10,952	77,6	0,14113
	Ternopil – Terebovlya	18140	35,192	16,048	35,4	0,45333
	Terebovlya – Zalishchyky	15280	29,643	13,517	87,7	0,15412
National Highways						
H-02	Lviv - Ternopil	8500	16,490	7,519	39,1	0,19230
H-18	Ivano-Frankivsk - Buchach - Tenopil	7600	14,744	6,723	73,6	0,09134
Regional Highways						
P-24	Tatariv – Kosiv – Kolomyia – Borshchiv – Kamianets-Podilskyi	2350	4,559	2,079	51,1	0,04068
P-26	Ostroh – Kremenets – Pochaiv – Radiviliv	4350	8,439	3,848	70,3	0,05474
P-32	Kremenets – Bila Tserkva – Rzhyshchiv	3200	6,208	2,831	30,9	0,09161
P-39	Brody – Ternopil	3910	7,585	3,459	40,7	0,08499
P-41	Bypass of Ternopil	5820	11,291	5,149	14,5	0,35510
P-43	/M-19/ – Lanivtsi – /R-32/	3780	7,333	3,344	56,2	0,05950
Territorial Highways						
T-20-01	Buchach - Chortkiv - Skala-Podilska				73,3	
T-20-01	Buchach - Chortkiv	2860	5,548	2,530	36,9	0,06856
T-20-01	Chortkiv - Skala-Podilska	1670	3,240	1,477	36,4	0,04058
T-20-02	Ternopil - Skalat - Zhvants	4600	8,924	4,069	171,8	0,02368
T-09-03	Halych - Pidhaytsi - Sataniv	4580	8,885	4,052	119,4	0,03394
T-20-04	Berezhany - Pidhaytsi - Monastyryshche	2920	5,665	2,583	47,6	0,05426
T-20-06	Horodyshche - Zarvanytsia - Buchach	3970	7,702	3,512	55,9	0,06283
T-20-07	Berezhany - Narayiv - Bryukhovychi	980	1,901	0,867	17,9	0,04844
T-20-08	Shumsk - Velyki Dederkaly - /R-32/	730	1,416	0,646	16,3	0,03963
T-20-09	Vyshnivets - Lanivtsi	810	1,571	0,716	24,6	0,02911
T-20-10	Zbarazh - Pidvolochysk	1170	2,270	1,035	40,1	0,02581
T-20-11	Kopychyntsi - Husiatyn	460	0,892	0,407	18,8	0,02165
T-20-12	Lanivtsi - Lysogirka - Teofipol	1080	2,095	0,955	9,1	0,10495
T-20-13	Pochaiv - Zboriv	980	1,901	0,867	57,1	0,01518

**Source: author's development.*

On international highways, significantly higher traffic intensity is observed. For example, the section between Ternopil and Pidvolochysk experiences a traffic flow of 19,800 vehicles per day. National highways, such as the Lviv-Ternopil route, show an average traffic intensity of 8,500 vehicles per day. On regional and territorial roads, the intensity is noticeably lower; for instance, on section T-20-01 between Buchach and Chortkiv, the traffic is recorded at 2,860 vehicles per day. Corresponding to the traffic intensity, international roads generate larger amounts of worn-off materials per day. For example, on the Ternopil-Pidvolochysk section, 38,412 kg of worn materials accumulate daily. Regional and territorial roads have significantly lower figures, such as on road R-24 (Tatariv-Kosiv-Kolomyia-Borshchiv-Kamianets-Podilskyi), where this figure is only 4,559 kg/day. International highways also exhibit higher daily masses of worn rubber per kilometer; for example, on the Ternopil-Pidvolochysk section, this is 0.43681 kg/km. For national and regional roads, these figures are lower, such as on road N-18 Ivano-Frankivsk-Buchach-Ternopil (0.09134 kg/km) and R-41 Bypass of the city of Ternopil (0.35510 kg/km).

Conclusions and perspectives.

The article provides an assessment of the role of the transport complex in the formation of environmental pollution by elastoplastic micromasses. The entry of micro-rubber particles into the environment, along with the release of dozens of chemical pollutants that are part of the material in vehicle tires, poses a threat to biodiversity, disrupts soil biomes, and reduces the quality of agricultural lands that are spatially adjacent to highways. Microplastic dust enters water bodies, accumulating on the bottom. The presence of microparticles in the atmosphere may cause diseases as these particles enter the bodies of humans and animals through the respiratory system. In addition, their entry into the atmosphere influences climatic processes, as repeatedly emphasized in scientific literature.

The development of mathematical and computer models for the spread and accumulation of elastomers that enter the environment as a result of the operation of vehicles in the Ternopil region requires the consideration of additional conditions and factors that describe these processes. These include climatic and weather conditions, the terrain, road configurations, traffic intensity and speed, and the direction of travel. Therefore, considering these parameters will allow, based on the obtained results, to build models of the spread of this type of pollution in the region, visualize them on maps, and make proposals to reduce the negative impact of elastomer pollution on the environment and public health.

References

1. Hruzdova, V.O., Koloshko, Yu.V., & Loboychenko, V.M. (2021). Doslidzhennya osoblyvostey zabrudnennya terytoriy mikroplastikom yak skladova zabezpechennya yikh ekolohichnoyi bezpeky [Study of the peculiarities of the contamination of territories with microplastics as a component of ensuring their environmental safety]. *Rozvytok silskykh terytoriy na zasadakh ekolohichnosti, enerhonezalezhnosti y enerhoefektyvnosti*: *II Mizhnar. nauk.-prakt. konf*. Poltava, 65-67.

2. Dorozhniy pyl vidnesly do osnovnykh dzherel mikroplastiku v povitri. Retrieved from https://nauka.ua/news/dorozhnij-pil-vidnesli-do-osnovnih-dzherel-mikroplastiku-v-povitri.

3. DBN V.2.3-4:2015 «Avtomobilni dorohy. Chastyna I. Proektuvannya. Chastyna II. Budivnytstvo». Retrieved from https://e-construction.gov.ua/laws_detail/3074920736381470676?doc_type=2.

4. Hutarevych, Yu.F. (Ed.). (2008). Ekolohiya ta avtomobilnyy transport: navch. posib. dlya vyshch. navch. zakl. [Ecology and road transport: a study guide for higher educational institutions] Kyiv: Aristey.

5. Kovalenko, L.O., & Hunko, I.S. (2020). Vyznachennya vykydiv zabrudnyuyuchykh rechovyn z urakhuvannyam rezhymiv rukhu transportnoho potoku [Determination of pollutant emissions taking into account traffic flow modes]. *Ekolohichni nauky* [Ecological Sciences], *1 (28)*, 206–210. Retrieved from https://doi.org/10.32846/2306-9716/2020.eco.1-28.32. [in Ukr.].

6. Madani, M.M. (2023). Vplyv avtotransportu na transformatsiyu ekosystem prydorozhnikh zon [The influence of motor vehicles on the transformation of ecosystems of roadside zones]. *Ahrarni innovatsiyi* [Agrarian Innovations], *17*, 99-106. [in Ukr.].

7. *Ternopilska oblast. Skhema planuvannya terytoriyi (prodovzhennya roboty). Tom I. Mistse oblasti v systemi rozselennya Ukrayiny, demohrafichnyy prohnoz, terytorialna orhanizatsiya ta struktura hospodarskoho*

kompleksu, propozytsiyi po rozvytku funktsionalno-planuvalnykh elementiv, prohnoz napryamiv rozvytku administratyvnykh odynyts [Ternopil region. Territory planning scheme (continued work). Volume I. The place of the oblast in the settlement system of Ukraine, demographic forecast, territorial organization and structure of the economic complex, proposals for the development of functional and planning elements, forecast of directions for the development of administrative units]. (2017). Kyiv: Derzhavne pidpryyemstvo Ukrayinskyy derzhavnyy naukovo-doslidnyy instytut proektuvannya mist «DIPROMISTO» imeni Yu. M. Bilokonya».

8. Tokschnyy pyl shyn mozhe buty nayhirshym z usikh dzherel zabrudnennya mikroplastykom. Retrieved from https://greentransform.org.ua/toksychnyj-pyl-shyn-mozhe-buty-najgirshym-z-usih-dzherel-zabrudnennya-mikroplastykom/

9. Zaporozhets, O.I., Boychenko, S.V., Matviyeyeva, O.L., Shamanskyy, S.Y., Dmytrukha, T.I., & Madzhd, S.M. (2017). *Transportna ekolohiya: navchalnyy posibnyk* [Transport ecology: study guide]. S.V. Boychenko (Ed.). Kyiv : NAU.

10. Fayfura, V., Manzhula, V., & Fayfura, V. (2023). Ekoloho-prostorovi aspekty zabrudnennya terytoriyi Ternopilskoyi oblasti mikroplastichnymy masamy [Environmental and spatial aspects of contamination of the territory of the Ternopil region with microplastic masses]. *Rehionalni aspekty rozvytku produktyvnykh syl Ukrayiny* [Regional Aspects of Productive Forces Development of Ukraine], *28*, 59-71.

11. Kharitonova, N.M., & Khrutba, V.O. (2021). Klasyfikatsiya dzherel mikrozabrudnyuvachiv yak skladovykh zabrudnennya poverkhnevykh dorozhnikh stokiv [Classification of sources of micropollutants as components of pollution of surface road runoff]. *Zbirnyk naukovykh prats «DOROHY I MOSTY» www.dorogimosti.org.ua ISSN 2524-0994. Dorogi i mosti* [Collection of Scientific Works «ROADS AND BRIDGES» www.dorogimosti.org.ua ISSN 2524-0994. Dorogi i mosti], *23,* 251-258.

12. Khrutba, V.O., Spasichenko, O.V., & Sarnavska, K.H. (2019). Kharakterystyka ekolohichnykh nebezpek miskykh transportnykh system [Characteristics of environmental hazards of urban transport systems]. *Zbirnyk naukovykh prats DUIT. Seriya «Transportni systemy i tekhnolohiyi»* [Collection of Scientific Papers of DUIT. Series «Transportation systems and technologies»], *33, 2,* 156-166.

13. Chynnyky, shcho vplyvayut na znos pokryshok. Retrieved from https://guma.com.ua/blog/articles/sho-vplivaye-na-znos-shin.html.

14. Shyny. Sproshcheno pro skladne … abo z yakykh komponentiv skladayutsya avtomobilni shyny Continental. Retrieved from https://www.automaster.net.ua/artykuly/shini-sprosheno-pro-skladne-abo-z-yakih-komponentiv-skladayutsya-avtomobilni-shini-continental,53697.

Received: 04.29.2024 / Review 06.18.2024 / Accepted 06.30.2024