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GREENING THE AUTOMOTIVE INDUSTRY: LEVERAGING ALUMINUM FOR ENVIRONMENTAL AND ECONOMIC ADVANTAGES

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***Summary.** Numerous strategic industries stand as prime candidates for the infusion of greeninnovation, with the transportation sector ranking second only to the energy industry in terms of global emissions. The continual escalation in the mass of automobiles and aviation fleets necessitates the development of novel methodologies, extending beyond the electrification of propulsion systems to encompass innovative material supply chain management. Aluminum, heralded as the preeminent eco-friendly material of the future, emerges as a particularly unique and influential instrument in this endeavor. In contemporary times, the weight of aluminum and its compounds in automobile production has eclipsed 70% in certain cases, underscoring its pivotal role in shaping the manufacturing landscape. Within the scope of this research, comprehensive analyses pertaining to green marketing strategies within the automotive and allied industries were conducted, unveiling the multifaceted environmental and economic benefits associated with the integration of aluminum materials.*

This article investigates how the strategic use of aluminum in the automotive sector not only enhances environmental sustainability but also yields substantial economic benefits. Aluminum's weight-saving properties and fuel efficiency improvements are pivotal in driving both environmental conservation and financial viability in the automotive industry.

Keywords: Sustainability, car industry, aluminum, innovation, green transport.

Introduction. The automotive sector is presently standing at a pivotal crossroads in its evolutionary journey. With a global drive towards more sustainable and environmentally friendly transportation solutions, automakers are facing escalating demands to curtail their carbon emissions and adopt eco-conscious materials and manufacturing methods. Within this paradigm shift towards sustainability, aluminum has risen to prominence as a central figure. Leveraging its exceptional blend of strength, lightweight attributes, and recyclability, aluminum has emerged as a transformative force in the quest to enhance vehicle fuel efficiency and promote ecological awareness.

In recent times, aluminum has been pushing other metals out of the market in world car production. From engine internals to spare parts, aluminum has begun to be widely used. As a light metal, aluminum has become a more demanded product in the world because it has switched to an ecologically low-consumption model. Aluminum offers a more affordable car for the future. This car is faster, lighter, less fuel-efficient, safer, and more environmentally friendly. Attention to the production of the main parts of the car from aluminum is increasing. Aluminum is included in the machinery industry in various combinations and brands.

In particular, the increase in electric vehicle production in recent years has further increased the demand for aluminum. The company "Tesla", which has implemented revolutionary innovations in the automobile industry, has designed a number of important parts of the electric car from aluminum alloys. Recently, the company began to install new aluminum-titanium armor plates on its cars. This tool allows you to literally crush concrete and steel barriers, while at the same time allowing the driver to fully control the car. The main negative aspect of aluminum for the automotive industry is that it is

relatively expensive. The high cost of production of some aluminum alloys affects their final market price in the automotive industry. For this reason, currently, cars made of aluminum are mostly in the luxury category. The CoMIT (Cost, Macro, Infrastructure, Technology) model is a sophisticated analytical tool designed for assessing the consequences of widespread Electric Vehicle (EV) adoption on the demand for critical raw materials. According to the model's projections, it is expected that by 2030, there will be a substantial increase in the demand for vehicles, with a significant uptick of 27.4%. Within this growth trajectory, Electric Vehicles are expected to make up approximately 13.3% of the total vehicle demand (Jones, Ellioe & Nguyen-Tien, 2020) [1]. The CoMIT model considers critical factors such as the cost implications of EV adoption, macroeconomic variables, infrastructure development, and automotive technology advancements, providing a holistic understanding of EV proliferation's impact on vital raw materials demand. This analysis is of great significance, offering valuable insights into the evolving automotive industry and its potential implications for resource consumption, environmental sustainability, and economic dynamics, thereby aiding policymakers, industry stakeholders, and researchers in informed decision-making for sustainable transportation and resource management in the next decade.

This kind of explorations delve into the potential ramifications on energy demand resulting from the impending shift to electric vehicles. It initiates by elucidating the motivating factors behind the transition from internal combustion engines to electric power, along with identifying key barriers obstructing this shift. It evaluates the diverse approaches used to implement this transition, encompassing an analysis of governmental policies and technological innovations. Finally, it addresses the expected consequences on existing electricity generation and distribution systems, and explores innovative technologies and emerging business models that could accommodate the substantial surge in electricity demand anticipated with the widespread adoption of Evs (Nieuwenhuis, Cipcigan, & Sonder, 2020) [2].

The new trend in the modern car industry, aluminum is used for the production of white bodywork, such as roof panels, doors, and hood panels. For example, the hid panels of automobiles like the "Audi A6, Renault Laguna II, and Peugeot 307" are aluminum bodyly parts. Aluminum alloy is used in the hood, roof, and door panels of the Renault Laguna II.

Many car manufacturers use aluminum alloys in a number of parts of the overall car production. Aluminum body panels have multifarious advantages, not only in reducing the weight of the car but also in decreasing the fuel consumption and increasing the maneuverability potential of the car.

What sets the aluminum body apart from other rigid and heavy steel-based alternatives is that it is also more environmentally friendly. In addition to energy and fuel consumption, the recycling of aluminum used as a raw material in car body parts has a potential of 99%. Apart from these, aluminum is also used in the engine, wheels, and other parts of the car.

Material and methods. Aluminum's applicability within the automotive industry extends far beyond its traditional role in forming body panels. It finds integration into a myriad of critical vehicle components, including engine blocks, suspension elements, wheels, and transmissions, among others. This diverse incorporation of aluminum is underpinned by its distinctive lightweight properties, which exert a profound influence on a vehicle's power-to-weight ratio. As a result, aluminum contributes significantly to the enhancement of overall automotive performance and efficiency. Furthermore, aluminum's exceptional malleability is a hallmark feature that empowers automotive designers and engineers to explore intricate and inventive designs. This malleable characteristic is pivotal in achieving a harmonious fusion of aesthetic appeal and functional innovation in contemporary vehicles. By capitalizing on aluminum's capacity to assume intricate shapes, automotive manufacturers can drive advancements in aerodynamics, structural engineering, and novel manufacturing processes. These endeavors collectively spearhead the ongoing evolution of automotive design and performance. Therefore, aluminum's adaptability serves as a cornerstone not only of its versatility but also of its pivotal role in propelling forward the frontiers of automotive engineering and design within the framework of sustainability and environmental consciousness.

Passenger cars were the biggest source of emissions that year, accounting for 41 percent of global transportation emission (Tiseo, 2023) [3]. In such statistical realities, when approaching epistemological bases along with green energy strategies, the development of a theoretical-methodological road map for the greening of the automobile industries with aluminum materials is of special importance.

The use of aluminum metal in car industry is strategic, but it is also scarce in terms of scientific materials. To implement the research, it is required to acquire theoretical and practical knowledge. Tizsa's comprehensive study (2014a) [4] and the subsequent collaborative work by Tizsa & Lukacs (2018a) [5] encompassed in-depth investigations into the utilization of aluminum within the automotive sector. Manufacturer Haomei Aluminum and the global information platform Aluminum Leader also have useful data exclusively for the car industry. The use of aluminum in the automotive industries is of particular importance from an eco-economic point of view. Theoretically and methodologically, the main research vectors are based on the principles of sustainable development. Basic green marketing and innovation features were expressed as the main criteria of the research.

Aluminum is the fastest-growing material in the car industry today. It is predicted that in 2026, every vehicle produced will contain an average of 12% aluminum (Huetter, 2020) [6]. In particular, the share of aluminum in today's fast-growing electric cars will show itself to be important. Innovative cars of the future will depend on aluminum.



Figure 1. Aluminum car model.

Photo source: Autoaluminumsheet.com

Research findings

Every kilogram of aluminum used in a car can lead to a decrease of one kilogram in the total weight of the car. As a result, more automobile components are made of aluminum, including engine radiators, rims, bumpers, suspension parts, engine cylinder blocks, gearbox housings, and body parts such as hoods, doors, and even the frame. Since the 1970s, the share of aluminum in the total heaviness of the average car has been steadily increasing. So, if in the 1970s an average of 35 kg of aluminum was used in a car, now this figure has risen to 152 kg. Experts predict that by 2025, the average amount of aluminum in a car will be 250 kg (Aluminumleader, 2015) [7].

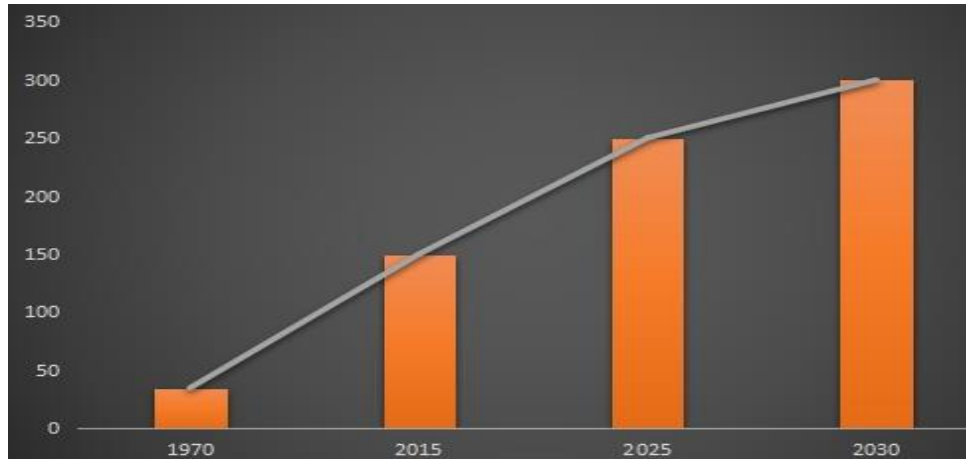


Figure 2. The portion of aluminum in the total mass of the car by years (in kilograms).

Another compelling statistic about aluminum in the automotive sector is its 95% recycling rate. This means 1 million tons of aluminum have returned to circulation in this area alone. 21 barrels of oil are saved for every ton of aluminum obtained through recycling. According to the calculations of the national laboratory "OAK Ridge" of the USA, a 20% reduction in total life cycle energy consumption and a 17% reduction in CO₂ emissions can be achieved (Das, 2020) [8].

Many alloy grades of aluminum are used in the automotive industry: 5xxx allow series (Al+Mg), 6xxx series (Al+Mg+Si), 7xxx series (Al+Zn), and 3xxx series (Al+Mn). For example, 5xxx is required for the main body of the car and 6xxx for the wheels (Haomei Aluminum, 2023) [9]. If it is expressed as a concrete brand, for example, car doors are mainly made of 5182 brand aluminum. Due to their improved physical, mechanical, and tribological qualities, aluminum composite materials have emerged as the material of choice for many architectural applications (Srivyas & Charoo, 2019a) [10]. Automobile producers have made a progression all-aluminum vehicles with two competing designs: the traditional unibody and the spaceframe concept. The rise in aluminum substitution for steel is influenced in part by regulatory pressures to meet fuel efficiency standards by reducing vehicle weight and to meet recycling standards (Tisza, and Lukacs, 2018b) [11]. The use of the so-called multimaterial principle is also becoming more common in today's vehicle body production (Tisza, M., 2014b) [12].

The advantages of aluminum for car manufacturing are as follows:

- Low fuel consumption: cars using aluminum have about 10% less energy-fuel consumption.
- Having a light weight has a positive effect on power and handling performance. Aluminum cars are around 20–30% lighter than other alternatives.
- Having profits in speed. Faster movement means more maneuverability.
- Increases safety. The lightweight the vehicle, the more secure it is. The greater the inertia of the vehicle, the greater the impact energy it will bear after the accident, and the more severe the repercussions of the accident.

By 2030, the global requirement for passenger-carrying plane alone is projected to exceed 30,000, and rapid growth will keep the importance of aluminum, which is of great importance to aircraft manufacturing, in constant focus. The main aspects that make aluminum alloys important for the aviation field and aircraft design are that they are light in weight, resistant to corrosion, and have high strength parameters. For example, aluminum is 70% lighter than iron and resistant to environmental influences. Apart from these, the following are the main advantages of aluminum for the aircraft industry:

- Resistance to high voltage, temperature, and pressure.
- Having high electrical conductivity.

- Having more cost-effective features than other alternatives.

The automotive industry is facing the challenge of increasing demand for lightweight and environmentally friendly vehicles that reduce energy consumption and air pollution. The distinctive characteristics of aluminum make it a promising material to replace the heavier materials currently employed in the automotive sector (Srivyas & Charoo, 2019b) [13]. While aluminum has found significant applications in the automotive industry, it faces certain challenges that warrant consideration. A prominent issue revolves around the production of primary aluminum, a process known to be energy-intensive and hence raising concerns about the environmental implications associated with aluminum mining and refining. Nevertheless, the industry is actively engaged in various initiatives aimed at enhancing the sustainability of aluminum production. These endeavors encompass the adoption of renewable energy sources in manufacturing facilities and continuous refinement of aluminum extraction and processing techniques to minimize their ecological footprint. Furthermore, as the use of aluminum in vehicles continues to grow, there is a pressing need to fortify recycling infrastructure. This strategic expansion is crucial to ensure the efficient collection and reintroduction of end-of-life aluminum components back into the manufacturing cycle. By establishing a robust and efficient recycling framework, the automotive sector can fully leverage the recyclable nature of aluminum, thus diminishing the demand for virgin materials and consequently reducing the environmental impact associated with primary aluminum production. This dual-pronged approach, which combines sustainable production methods with improved recycling practices, is instrumental in charting a more environmentally responsible and resource-efficient course for the future of the automotive industry.

Conclusion

A number of strategic industries of environmental and economic importance were analyzed in the research work. As the main object, the possible application methods of aluminum materials, with green principles as the basis, have been elaborated. The main goal of scientific research on this topic, which is also considered a branch of green supply chain management, is to make a small contribution to the sustainable future of the world.

The scientific article points to new visions of the future by showing ways of using aluminum metal in the machinery and aviation industries. The utilization of aluminum in these industries can lead to 10–30% green benefits. The data revealed in the research, the information collected on one platform, the specific material names, and the future predictions have useful nuances for all researchers interested in this field. The goal of the research written in the form of a review is to be useful to the scientific environment of Turkey and Azerbaijan, which specialize in the aluminum industry in the region.

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Avtomobil sənayesinin yaşllaşdırılması: ekoloji və iqtisadi üstünlüklər üçün alüminiumdan istifadə

R. İ.Həsənov

Xülasə.Çoxsaylı strateji sənayelər yaşıl innovasiyaların tətbiqi üçün əsas namizəd kimi dayanır və nəqliyyat sektoru qlobal emissiyalara görə enerji sənayesindən sonra ikinci yerdədir. Avtomobil və aviasiya sənayələrinin kütləsinin davamlı artması, innovativ material tədarük zəncirinin idarə edilməsini əhatə etmək üçün hərəkət sistemlərinin elektriklişdirilməsindən də kənara çıxan yeni metodologiyaların işlənilməsinə tələb edir. Gələcəyin ekoloji cəhətdən təmiz materialı kimi elan edilən alüminium bu işdə xüsusilə unikal və təsirli alət kimi çıxış edir. Müasir dövrdə avtomobil istehsalında alüminiumun və onun birləşmələrinin çəkisi bəzi hallarda 70%-i üstələyib və bu kimi amillər onun istehsal landşaftının formalaşmasında əsas rol oynayır. Bu tədqiqat çərçivəsində alüminium materialların inteqrasiyası ilə əlaqəli çoxşaxəli ekoloji və iqtisadi faydaları ortaya çıxaran avtomobil sənayesi daxilində yaşıl marketing strategiyalarına aid geniş təhlillər aparılmışdır.

Bu məqalə avtomobil sektorunda alüminiumun strateji istifadəsinin nəinki ekoloji dayanıqlığı artırdığını, həm də əhəmiyyətli iqtisadi faydalar verdiyinə də önəm vurğulayır. Alüminiumun çəkiyə qənaət edən xüsusiyyətləri və yanacaq səmərəliliyinin təkmilləşdirilməsi həm ətraf mühitin qorunmasında, həm də avtomobil sənayesində maliyyə dayanıqlığının təmin edilməsində mühüm əhəmiyyət kəsb edəcəkdir.

Açar sözlər: davamlılıq, avtomobil sənayesi, alüminium, innovasiya, yaşıl nəqliyyat.

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Экологизация автомобильной промышленности: использование алюминия для получения экологических и экономических преимуществ

Р. И. Гасанов

Резюме.Многочисленные стратегические отрасли промышленности являются главными кандидатами на внедрение «зеленых» инноваций, при этом транспортный сектор занимает второе место после энергетической отрасли по объему глобальных выбросов. Постоянное увеличение количества автомобилей и авиации требует разработки новых методологий,

выходящих за рамки электрификации двигательных систем и охватывающих инновационное управление цепочками поставок материалов. Алюминий, провозглашенный выдающимся экологически чистым материалом будущего, становится особенно уникальным и влиятельным инструментом в этом начинании. В настоящее время вес алюминия и его соединений в производстве автомобилей в некоторых случаях превысил 70%, что подчеркивает его ключевую роль в формировании производственной среды. В рамках этого исследования был проведен комплексный анализ стратегий зеленого маркетинга в автомобильной и смежных отраслях, раскрывающий многогранные экологические и экономические выгоды, связанные с интеграцией алюминиевых материалов.

В этой статье исследуется, как стратегическое использование алюминия в автомобильном секторе не только повышает экологическую устойчивость, но и дает существенные экономические выгоды. Свойства алюминия по снижению веса и повышение эффективности использования топлива имеют решающее значение для сохранения окружающей среды и финансовой жизнеспособности автомобильной промышленности.

Ключевые слова: устойчивое развитие, автомобильная промышленность, алюминий, инновации, экологически чистый транспорт.

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