

## GREEN PROCUREMENT AND GREEN TRANSPORTATION: THE CASE OF THE ALUMINUM INDUSTRY

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**Abstract.** The procurement and transportation operations conducted by national, state, and local governments directly or indirectly contribute to global greenhouse gas (GHG) emissions. Carbon dioxide emissions arising from the procurement and transportation sectors, in conjunction with emissions originating from industrial activities, have collectively surpassed 50% of the global carbon emissions. In light of this context, the crucial imperative is to undertake a transition towards implementing green management standards within the supply chain system. The significance of green procurement (GP) and green transportation (GT) extends beyond mere importance and holds vital implications for the sustainable future of our planet. Therefore, the transition towards incorporating these principles is of utmost importance. Within the context of the aluminum industry, which plays a strategic role in the global economy, exploring its integration into the framework of green scientific research becomes an essential area of investigation. The primary objective of this article is to comprehensively analyze and examine this critical issue to shed light on its complexities and implications.

**Keywords:** *Green Supply Chain Management, Aluminum Industry, Green Economics, Energy, Business Management, Sustainability, Climate Change.*

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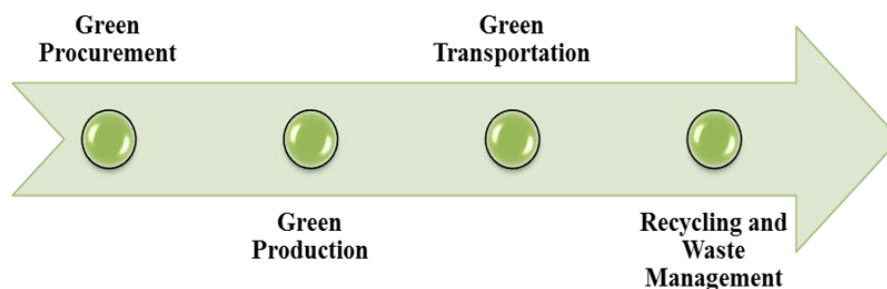
### 1. Introduction

Scholarly publications have introduced the concept of GSCM over the years, emphasizing its increasing significance. Embracing environmentally conscious practices has become essential for ensuring the long-term sustainability of our planet. The integration of eco-friendly principles has made significant advancements in the field of supply chain management, occupying a prominent position. This progress reflects the growing recognition of the environmental impact of supply chains and the urgent need to mitigate it through sustainable measures. By incorporating green strategies and technologies, organizations can establish a more sustainable and resilient supply chain, thereby making a positive contribution to environmental preservation. The imperative of green business management lies not only in its intrinsic significance, but also in its role as a catalyst for devising novel solutions to address specific environmental challenges, thereby enabling organizations to thrive and remain competitive in the ever-evolving global economic environment.

The stages of inbound logistics, green production, outbound logistics, green packaging, and reverse logistics are essential elements within the framework of the green supply chain management (GSCM) system, working together to establish a comprehensive structure for incorporating environmentally sustainable practices across

the entire supply chain (Achillas *et al.*, 2019). Hasanov and Safarli (2023) put forth a set of contemporary principles pertaining to the GSCM system. Simultaneously, authors introduced an innovative structural eco-design model as part of their scholarly contributions.

The GSCM system, which encompasses diverse economic sectors including the metallurgical industry, can be conceptualized through four key stages: green procurement, green production, green transportation, and recycling and waste management, serving to facilitate the adoption of environmentally sustainable practices across the entire supply chain.



**Figure 1.** Main stages of GSCM in general.

**Source:** Authors' finding.

While the aluminum industry exhibits higher CO<sub>2</sub> emissions during its production process compared to other industries, it is crucial to acknowledge the significance of other stages, particularly GP and GT, in achieving overall sustainability objectives.

GSCM recognizes the crucial role of procurement as the starting point in the supply chain, responsible for ensuring the timely supply of raw materials and equipment to all plants within a complex system. Even minor deficiencies in this process can lead to significant complications in the overall operation of the complex. In order to optimize the aluminum industry according to green principles, it is necessary for the traditional procurement process to undergo transformation. Therefore, the initial strategic step in GSCM should focus on implementing a green procurement phase, which encompasses the environmentally conscious acquisition of bauxite as the primary raw material for obtaining aluminum oxide, essential for the production of pure liquid aluminum.

Green transportation serves as a vital stage within the framework of GSCM, representing the final phase of delivering manufactured products to buyers. It is noteworthy that transportation-related greenhouse gas (GHG) emissions contribute significantly to the overall GHG emissions, accounting for approximately 29 percent of the total GHG emissions in the United States, thereby constituting the largest contributor to the nation's GHG emissions (EPA, 2023). In order to optimize the green transport system in alignment with sustainable principles, the adoption of environmentally friendly transportation modes, such as ships and trains, becomes imperative. These options hold particular relevance for the aluminum industry, given its extensive and intricate supply chain network. By prioritizing the utilization of eco-friendly transport modes, the aluminum industry can make substantial progress towards achieving sustainability goals and fostering a greener future.

## 2. Theoretical background

Numerous recent articles within the scientific literature offer separate investigations and insights into the topics of GP and GT, contributing to a comprehensive understanding of these areas within the broader framework of GSCM. The study conducted by Fahimnia et al. (2015) served as an introduction to the subject matter by examining key considerations and initiating a discourse on the pivotal role of green logistics and transportation in fostering sustainability within supply chains. The research provided a comprehensive overview of general issues encompassing the implementation of environmentally friendly practices, including greening the supply chain, optimizing logistics networks, and improving freight and public transportation systems. Routroy and Pradhan's (2012) seminal work delved into a comprehensive exploration of green procurement, with a particular emphasis on the intricate interrelationships among environmental factors, quality standards, and pricing dynamics. In their extensive review, Vejaratnam et al. (2020) identified five overarching themes, namely finance, legal, people, knowledge, and organization, which emerged from the analysis and further encompassed 16 sub-themes. Notably, the study revealed that a key obstacle for GP implementation was the prevalent lack of knowledge and awareness regarding sustainable practices.

The edited book by Psaraftis (2016) extensively explored the topic of sustainable logistics, offering a comprehensive analysis from policy and environmental perspectives. It specifically highlighted the importance of incorporating environmental criteria when formulating logistics optimization problems. The scholarly work of Shah et al. (2021) involved a thorough examination and evaluation of crucial factors that warrant careful consideration in the implementation of green transportation, aiming to achieve sustainability on a global scale. Lee et al. (2017) proposed that the establishment of a proficient GT system can yield various benefits, including mitigated risks, alleviated traffic congestion, improved energy and resource sustainability, reduced pollution and accidents, enhanced safety and security measures, optimized travel speed, and optimized traffic flow. Concurrently, a crucial facet pertains to the appraisal of green energy potential within the context of a specific country, as elucidated in the same author's subsequent publication (Hasanov, 2023).

## 3. Methodology

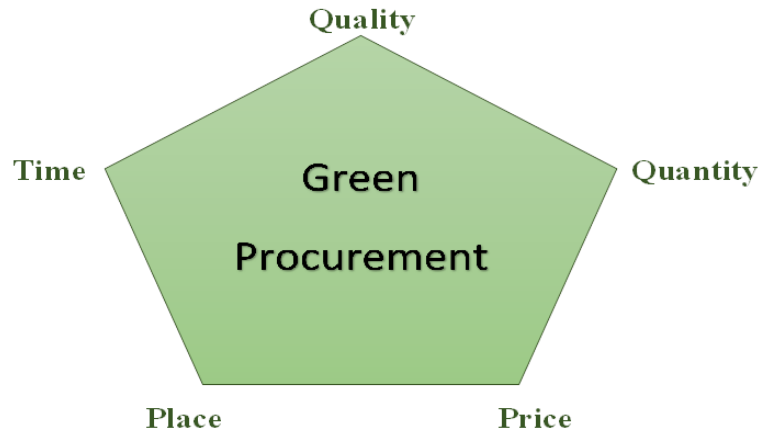
When examining structural methodologies for research on GP and green transportation in the aluminum industry, it is important to take into account multiple factors. GP management primarily revolves around the sourcing and management of raw materials, while GT management pertains to the shipping and logistics aspects of finished product transportation. Both areas play critical roles in implementing sustainable practices within the aluminum industry and require careful consideration and analysis for effective and environmentally conscious strategies.

The following raw materials are the primary strategic dependencies for primary aluminum production:

- Anode blocks
- Aluminum oxide ( $Al_2O_3$ )
- Cryolite

Purchasing principles require an assessment of both the external and internal business environments. A manufacturing enterprise's procurement products are divided into strategic and routine categories. Aside from the economic importance of raw materials such as aluminum oxide and anode, the environmental aspects are also significant, and as a result of these factors, the organized construction of the GP stage is consequential.

The first stage of implementing eco-economic principles in GSCM is general planning. The main directions of a profitable exit at the GP stage can be described in pentagon angles: right quality (Q), right quantity (Q`), right price (P), right time (T), and right place (P`).



**Figure 2.** The Pentagon model of GP management.  
**Source:** Authors' finding.

The main principle in green procurement is to determine the best strategy and the lowest of the chosen minimums and highest of the maximums. The following formulas can express this principle:

$$GP = \max (\max Q1, \max Q2, \dots \max Qn)$$

$$GP = \max (\max Q`1, \max Q`2, \dots \max Q`n)$$

$$GP = \min (\min P1, \min P2, \dots \min Pn)$$

$$GP = \min (\min T1, \min T2, \dots \min Tn)$$

The execution of transportation can have a different character due to two features:

- Geography and infrastructure
- Business situations

GT from Azerbaijan to the US and EU markets, where there is a high demand for aluminum, is done by rail and ship, while transportation to Turkey and Russia is performed by rail. Green logistics and transportation goals can primarily be examined through two lenses:

- The primary strategic goal is to select green logistics providers, green vehicles, and green distribution strategies.
- The main goal in terms of operations is to organize a green transportation schedule in order to solve delivery schedule and efficient inventory management issues.

#### 4. Research Findings

One of the fundamental principles of GSCM is obtaining more profitable and higher-quality raw materials from global markets. Aluminum oxide accounts for approximately 90% of global aluminum production. Another major reason for the rapid increase in global alumina production is its widespread use in the production of ceramics. China is the world's largest alumina producer. China produced 71 million tons of alumina in 2021, accounting for 53% of the global total. Australia came in second place, with 15% of the total production capacity (Statista, 2021).

Alumina production is one of the most urgent problems. China, the world's largest producer of alumina, has been using more coal as an energy source, causing massive emissions into the atmosphere. Concerned about environmental pollution, the Chinese government reduced alumina production by 30% during certain periods (Rimsa, 2023). The world's major aluminum institutes, companies, and organizations supporting green strategies are working to transition alumina production to waste-free technologies. At the same time, new green trends in the global market give preference to trade with manufacturing enterprises that emit fewer emissions and use more alternative energy. According to Research and Markets, the global alumina market was worth more than \$5 billion USD in 2021 and the same research bureau predicts \$7.72 billion in 2027, assuming the current rapid growth (Research and Markets, 2022).

Anode blocks are the second most important raw material for liquid aluminum production. Anode blocks are made of dense, hard, and long-lasting carbon. China, as the world's largest producer of aluminum, has a sizable market share for carbon anode blocks. The Shanghai Metals Market is a key location for determining anode prices. China's major anode manufacturers include Sunstone, Guangxi Qiangqiang, Jinan Aohai, Jining Carbon, Dezhou Yongxing Carbon, and Jinan Wanfang Carbon. Aluchemie of the Netherlands, Rheinfelden of Germany, Carbonorca of Venezuela, Rain CII of the United States, and Lake Charles companies are among the world's largest anode producers (Gupta, 2017). Significant price increases have occurred in the anode market in recent years. The primary reason was a high increase in the value of coke and coal tar, both of which are required raw materials for anode production. These materials' prices increased by 80% between 2017 and 2018 (Goran, 2018). Calcined coke is critical in assessing the anode market. China also serves as the primary coke supplier for liquid aluminum producers.

The timely and efficient provision of anode blocks and alumina in the GP system is critical. The import of anode blocks accounts for approximately 35% of the total cost of aluminum production. The increase in transportation costs in the global economy has also had a significant impact on the anode import price and increased its cost in aluminum production. One of the primary factors determining both economic profit and environmental sustainability in the GP strategy is the purchase of a high-quality and reasonably priced anode.

Cryolite is a strategic ingredient required for aluminum production. A small amount of addition during the continuous production process regulates the amount of cryolite, which is primarily determined during the initial construction and later regeneration of the electrolysis baths. Cryolite serves an important technological purpose. A temperature of around 2000 °C is required for the electrolysis separation of aluminum from clay soil to occur. The temperature of this chemical process can reach 900-950 °C when the cryolite substance is added. The greatest eco-economic necessity of cryolite is precisely in its

chemical-technological role (Kvande, 2011). The aluminum industry consumes more than 30% of the world's cryolite production. A number of innovative cryolite production technology projects are being implemented. In July 2021, Alcore, a subsidiary of Australia's ABx, used some novel methods to produce aluminum fluoride from pure sediment. Through a process, the Alcorn Company was able to separate the aluminum fluoride from the sediments. Eclipse Metals has also signed several new projects in Greenland mines to implement such new innovations (Market Research Future, 2023). Greenland is well-known for having cryolite reserves. Furthermore, in the cryolite market, countries such as Spain and the United States can be mentioned. In order to effectively manage purchases, a vendor list is compiled. Preliminary marketing information is required for the purchase of strategic products, and thus the information of its main global suppliers for each material should be formed in advance in purchasing departments.

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**Figure 3.** Vendor list for cryolite purchase.

**Source:** Authors` finding.

Cryolite orders, compliance with environmental standards, the green platforms of the selling companies, and all shipping criteria, should be considered in green procurement principles.

The procurement process is based on open tenders, requests for proposals, and quotations. Ensuring transparency and honesty during the process is one of the main indicators of quality. The procurement process at Azeraluminum LLC is carried out according to the Law on State Procurement of the Republic of Azerbaijan, the relevant decree of the President of the Republic of Azerbaijan, and the company's internal rules (Azeraluminium, 2023).

In order to analyze the eco-economic indicators of companies in the GP management system, statistical studies in specific equivalents and quantities are required. Analyses of strategic products, which have a high economic burden and necessity for

environmental assessment, are foremost and one of the main functions of GP management.

The name of the product	Price	Transportation cost (From the Port of Poti)	Country of import
1. Aluminum oxide	480\$	45\$	Jamaica, Guinea
2. Anode blocks	1550\$	48\$	China, Turkey
3. Aluminum fluoride	980\$	48\$	Russia, Belarus
4. Cryolite	1750\$	45\$	China

**Figure 4.** Purchase indicators of the main procurement products for the Ganja Aluminum Complex in 2022 (per 1 ton).

**Source:** Authors` finding.

Prioritizing green transportation saves the environment while also increasing economic profit. However, at times, a variety of business-related requirements can necessitate sudden changes in mode of transportation. To avoid additional costs in railway transportation, carriages in both directions must be full. One of the most crucial planning factors for GT efficiency is sending and receiving goods on the same train.



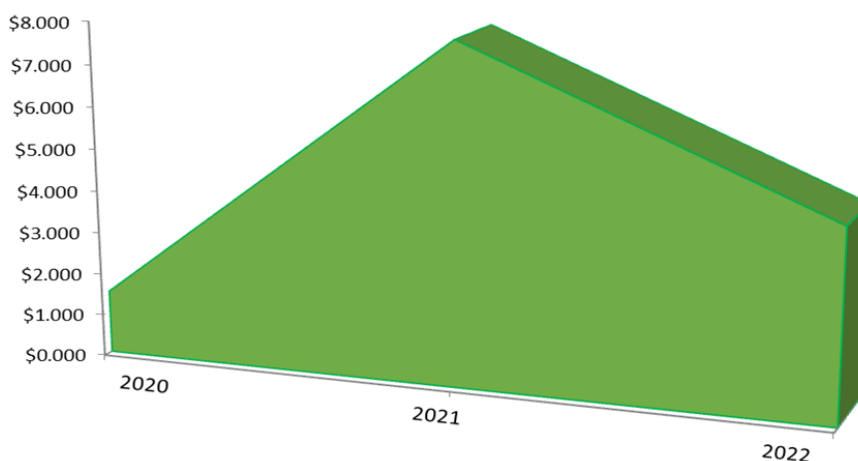
**Figure 5.** Green transportation from Azerbaijan to the USA and Turkey.

**Source:** Authors` finding.

The main green principle is to supplement the efficiency of railroad transportation with a variety of measures. Import transportation is just as significant as export transportation. Transportation of imported products is required for any company, and an agreement was reached with another Azerbaijani company, ADY Konteyner LLC, to achieve cost-effective import and export transportation in the region. Transportation on

the Trans-Caspian International Transport route has been made possible by the establishment of a new logistics model with ADY Container LLC, a subsidiary of Azerbaijan Railways, and a train block consisting of 50 containers moving from Gujing, People's Republic of China, has arrived at Ganja Aluminum Complex within 30 days. Products are exported from Azerbaijan to Turkey via the Baku-Tbilisi-Kars railway in a block train carrying 74 containers as part of the "TURKUAZ" project (ASK, 2022). ADY Container was founded with the goal of improving the quality and safety of cargo transportation by rail, as well as centralized implementation and efficient management of container transportation. According to the 1.7 million dollars contract signed with Azeraluminum Company, 3,264 tons of baked anode blocks were transported by rail in containers from China to Ganja station (Banker, 2022). Building large-scale cross-business networks with both international and domestic shipping companies benefits the entire non-oil sector ecosystem.

The most serious problem with transportation in recent years has been the rapid rise in service prices. The unexpected rise in transportation costs, which is directly related to and influenced by global inflation. International transportation costs have increased fourfold in the last two years. This situation increased the price of the product and caused global market perturbation.



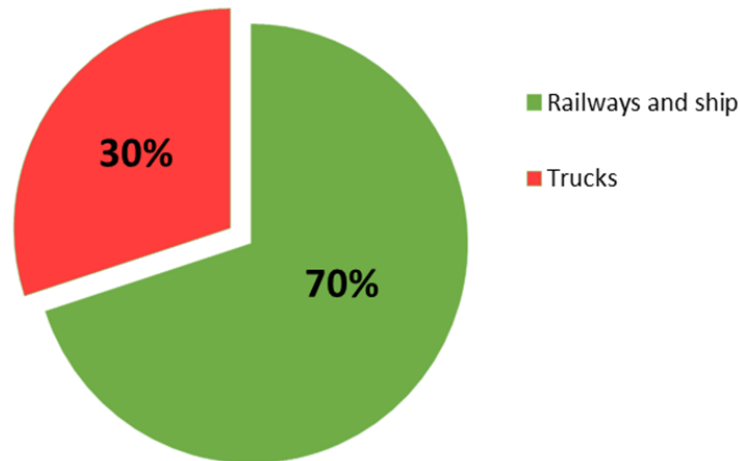
**Figure 6.** Dramatic changes in shipping costs to the US for 1 container(20T) of aluminum.  
**Source:** Authors` finding.

CO<sub>2</sub> emissions from heavy-duty trucks and buses powered by internal combustion engines account for approximately 6% of total EU emissions (Europa, 2023). Combined emissions from rail and ship transport are significantly lower than those from road transport. There are already electric versions of heavy trucks, and improvements are being made in this sector as well. It may come as no surprise that in the near future there will be a massive emergence of logistics companies carrying out transportation operations with all-electric heavy-duty trucks. One of the issues to be resolved is that companies should define the introduction of new innovations in the management of R&D as the main strategy. The transition to electric vehicles is at the heart of global R&D strategies. According to Mike Tinsky, Ford Motor Company's deputy director of global electrification infrastructure, a person driving a Focus electric car will save approximately one ton of CO<sub>2</sub> emissions per year when compared to a gasoline equivalent (Warren, 2012). During the production process in the aluminum industry, there is always a high



volume of traffic in the factories and workshops. The vehicles that implement this system run on fuel and transport liquid aluminum, anode blocks, ingots, coils, and repair equipment on a continuous basis. A rational solution to the problem can be initiated by replacing the cars in the electrolysis, anode, and foundry factories with new electric-powered vehicles.

Some statistics are sufficient to convince a global corporation to prioritize green transportation in its business strategies. Normative documents such as the International Transport Regulation and railroad and ship bills of lading are prepared for product transportation, and goods are loaded, insured, and delivered in accordance with Incoterms.



**Figure 7.** Green transportation indicator in the Ganja Aluminum Complex (2022).

**Source:** Authors' finding.

GT is executed by three main means of transport: railways, ships, and trucks. Aluminum products are mostly considered environmentally friendly when transported by rail and ship. Given the growing interest in solutions for eco-economic sustainability in the process of globalization, the current transportation system must be transformed into sustainable green transportation in the future through the implementation of innovative technologies and management strategies (Kinjal, 2021). GT is considered one of the final missions of the unified system model for the successful implementation of GSCM.

## 5. Conclusion

The organization of sustainable supply chain management is a vital aspect of promoting the principles of the green economy. In the modern global business landscape, the adoption of GSCM standards has become an imperative requirement for facilitating efficient and environmentally conscious economic activities. This scientific article presents a comprehensive analysis of GP and GT management within a specific industrial sector. The research delves into global theoretical foundations and selects the Ganja Aluminum Complex, the primary and semi-finished aluminum production enterprise in the Caucasus region, as a practical research subject.

The study showcases the principles, provisions, and statistical data pertaining to GP and GT for this exemplary manufacturing facility, providing a valuable reference for implementing sustainable practices throughout the supply chain system. The research

work presents a notable scientific innovation by focusing on an in-depth examination of the specific and strategically significant aluminum industry. Consequently, the article encompasses valuable aspects that hold relevance for both scientific researchers seeking to advance knowledge and industrial circles looking for practical insights and implications.

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