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RESEARCH

Reverse Logistics in the management of packaging and packaging waste in the context of COVID-19

La Logística Inversa en el manejo de los residuos de empaques y embalajes en el contexto del COVID-19

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Abstract

The new challenges currently faced by companies regarding reverse logistics during the COVID-19 crisis are numerous, such as high uncertainty in supply timing, quantity, and quality. During this crisis, there has also been an increase in the use of plastic packaging due to health protocols and safety measures, making them unrecyclable and creating the need to modify practices to protect the environment. In this context, reverse logistics provides knowledge about ways to reintegrate goods, which have gone through production processes, back into the market as an alternative to identify the main factors characterizing environmental impact in the product supply chain. The aim of this study is to provide a review and content analysis of the scientific literature on reverse logistics in order to establish a reference framework and conceptualize the management of packaging and packing waste. The paper concludes by offering a reasoned characterization of this new aspect of reverse logistics to reflect on the adoption of best practices in packaging logistics, aligning existing standards with current needs.

Keywords: Reverse Logistics, waste, reuse, COVID-19.

JEL Codes: Q57, M1, L60

Resumen

Los nuevos desafíos que actualmente enfrentan las empresas sobre la logística inversa durante la crisis de la covid-19 son varios, tales como alta incertidumbre de suministro en tiempo, cantidad y calidad. Durante esta crisis, también ha habido un aumento del uso de empaques de plástico debido a los protocolos y cuidados sanitarios, por lo que no podrán ser reciclados surgiendo con ello la necesidad de modificar prácticas para proteger al medio ambiente. En este sentido, la logística inversa proporciona el conocimiento de las formas de reintegración al mercado de los bienes beneficiados por los procesos de producción como una alternativa para identificar los principales puntos que caracterizan el impacto ambiental en la cadena productiva de algún producto. El estudio tiene como objetivo proporcionar una revisión y análisis de contenido de la literatura científica de estudios de logística inversa con la finalidad de proporcionar un marco de referencia y conceptualizarlo sobre el manejo de residuos de empaques y embalajes. el trabajo concluye proporcionando una caracterización razonada de esta nueva parte de logística inversa para reflexionar sobre la adopción de mejores prácticas de la logística de empaques y embalajes, conjuntando las normas existentes con las necesidades actuales.

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Palabras claves: Logística Inversa, residuos, reutilización, Covid-19.

Código JEL: Q57, M1, L60

1. Introduction

A few years ago, logistics was basically related to the management of a company's supply chain. Today, the definition of logistics is much broader and is characterized by being complex, dynamic, and uncertain. This is partly due to the impact of economic and environmental regulations, which have created a new set of general problems within reverse logistics (Bei and Linyan, 2005; Feal Vázquez, 2010).

Reverse logistics has become one of the most relevant aspects of logistics, attracting increasing attention from professionals and researchers in recent decades. For over thirty years, supply chains have been diligently optimized from raw materials to end customers. Under different approaches, supply chain managers have typically thought "forward," focusing on the downstream movement of products. It is now widely accepted that reverse logistics is a key competency in modern supply chains and, as such, must be properly managed (Ortega Mier, 2008).

Challenges in this field have been caused by the rapid growth of e-commerce, the rise of online retailers, and similar developments. Competition is fiercer than ever in most markets, product life cycles have shortened, and business conditions are constantly changing. Once again, companies suffer major losses due to high return volumes driven by return policies. Therefore, to add value for customers, improve customer relationships, and strengthen their competitive advantages, companies must find ways to reduce waste and recover value from used products for other purposes. These factors have pushed companies to reshape their strategies. New topics such as Global Manufacturing, Third-Party Logistics, Alliances, e-Logistics, and SMEs have emerged. All of these challenges make reverse logistics a contemporary area of interest for managers and researchers alike (Soto and Ramalhinho, 2002; Bei and Linyan, 2005).

In today's context, and in the wake of the COVID-19 pandemic, several sectors of society have been affected, and logistics in businesses has been no exception. However, not all consequences have been negative. In the case of logistics, it has taken on an important role due to the sharp increase in online sales. While this has benefited society by preventing virus spread, it has posed a major challenge for reverse logistics, which must now adapt its usual practices to the standards and protocols of the "new normal." Moreover, due to the rise in waste (e.g., containers and packaging), raising awareness among companies and encouraging them to implement reverse logistics as a primary activity plays a key role in our society's future benefiting the environment above all and also having a positive impact on economic and social aspects.

In light of the above, the aim of this study is to provide a review and content analysis of scientific literature on reverse logistics to establish a reference framework and conceptualize its role in the management of packaging and packing waste. To achieve this objective, the first section analyzes the evolution and emergence of the concept of reverse logistics and its ties to environmental concerns and economic drivers. The notion of reverse logistics is addressed in both broad and narrow terms, including differences between reverse logistics and traditional forward logistics. The third section explores the management of waste through reverse logistics within the supply chain. The fourth section discusses the challenges reverse logistics faces in the context of COVID-19. Finally, brief conclusions are presented.

2. Literature review

2.1 Background of reverse logistics

A few years ago, logistics was essentially tied to the management of a company's supply chain. Today, the definition is much broader. Modern logistics considers topics that fall within the realm of public policy decisions locally, nationally, and internationally such as transport infrastructure and logistics activity zones (Feal Vázquez, 2010).

Regarding reverse logistics, this area has received growing attention, especially over the last decade, due to the convergence of various factors. As noted by Fernández (2003) and Rahman and Subrayarían (2012), there is a clear concern for environmental issues and sustainable development. In addition, economic motivations have contributed to the growing importance of reverse logistics, as returned products allow companies to recover both raw materials reducing future purchasing needs and added value. Whether savings come solely from reduced material purchasing costs or from materials, labor, and overhead, companies are increasingly interested in participating efficiently in reverse logistics as competitive pressure narrows profit margins.

Given this scenario, and perhaps due to its growing relevance, the concept of reverse logistics remains vaguely defined. As several authors have argued (Fleischmann, 2000; Mason, 2002; Soto and Ramalhinho, 2002; Kivinen, 2002; Tan and Kumar, 2003), there is still no widely accepted definition of reverse logistics in practice, partly due to the wide range of related topics activities, products, supply chain points, and so on.

According to the literature review, Quesada (2003) notes that early authors such as Beckley and Logan (1948), Terry (1869), and Giultinian and Nwokoye (1975) had already addressed product returns, although not referring to them as part of reverse logistics flows. Murphy & Poist (1989) are among the first to use the term "reverse logistics." They introduced "reverse distribution" as an equivalent term, and this dual terminology has persisted in some studies (Barry et al., 1993; Carter and Ellram, 1998; Jayaraman et al., 2003).

However, contributions to the understanding of reverse logistics began in the 1960s and 1970s (Seitz and Wells, 2006). One of the most comprehensive studies in the field was conducted by Kopicki et al. (1993), who observed that companies implementing environmentally conscious programs typically go through three phases: reactive, proactive, and value-seeking. Recently introduced environmental standards often force companies into reactive responses.

It wasn't until the 1990s that the management of reverse logistics systems and the term "reverse logistics" (in English, "reverse logistics" or "inverse logistics") were more thoroughly studied (Ortega Mier, 2008).

Regarding the origins of the term, in 1992, the Council of Logistics Management (CLM) defined reverse logistics as the role of logistics in recycling, waste disposal, and hazardous materials management. A broader perspective includes all logistics activities related to source reduction, recycling, substitution, reuse of materials, and disposal (De Brito and Dekker, 2003:17).

Thus, given the short history of reverse logistics and the relatively recent research in the field, it is understandable that a universally accepted terminology has yet to be established.

2.2 What is reverse logistics?

To illustrate the various interpretations found in the literature, this study considers the definitions identified in the literature review, which are regarded as relevant within the field of reverse logistics and serve as a foundation for this area of research.

In one of the first referenced publications, edited by the Council of Logistics Management (CLM), Stock (1992) introduces reverse logistics as "the term normally used to refer to the role of logistics in recycling, waste disposal, and the management of hazardous materials. A broader perspective includes all activities related to material reduction, recycling, substitution, and the reuse of materials and waste" (Ortega Mier, 2008, p. 19).

A similar definition is offered by Kopicki (1993), also from the CLM: "it is a term that refers to the logistics management capabilities and activities involved in the reduction, management, and elimination of hazardous or non-hazardous materials, ranging from packaging to final products. It includes reverse distribution, as just defined, which causes the flow of products and information in the opposite direction to normal logistics activities" (Ortega Mier, 2008, p. 19).

Krikke, H. (1998) defines Reverse Logistics as the collection, transportation, storage, and processing of discarded products.

Fleischmann (1997) states that Reverse Logistics is a process that encompasses logistics activities from used products that the user no longer needs to products that can be reused in the market.

Dowlatshahi, S. (2000) explains Reverse Logistics as a process in which a manufacturer systematically accepts previously shipped products or parts, from the point of addition for possible recycling, remanufacturing, or disposal.

V. Daniel (2000) says that Reverse Logistics is the task of recovering discarded products (cores); it may include packaging and shipping materials and bringing them back to a central collection point for recycling or remanufacturing.

Kroon and Vrijens (1995) say that Reverse Logistics involves the skills and logistics management activities related to the reduction, management, and disposal of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution, which causes goods and information to flow in the opposite direction to normal logistics activities.

Finally, Rogers, D. and Tibben-Lembke, R. (1998), define Reverse Logistics as the process of planning, implementing, and controlling the efficient and cost-effective flow of raw materials, in-process inventory, finished products, and related information from the point of consumption back to the point of origin for the purpose of recapturing value or proper disposal. Considering the elements of these definitions, we believe the definition given by Rogers, D. and Tibben-Lembke, R. (1998) is the most complete and incorporates the main characteristics of what we think Reverse Logistics is.

2.3 Green logistics

A common problem when talking about Reverse Logistics is the confusion between reverse logistics and green logistics. The threat posed by the scarcity and deterioration of natural resources has made companies more aware of the need (obligation in some countries) to develop green alternatives or ecological ways of doing business. Reverse logistics is often confused with the concept of green logistics. Redesigning packaging to use less material or reducing energy and pollution from transportation are important activities but could better fit under the umbrella of "green" logistics.

If goods or materials are not sent "backwards," the activity is unlikely to be a reverse logistics activity. The confusion remains because most reverse logistics activities fall within the green logistics area. (Soto and Ramalhinho, 2002).

According to de León, Zavala, and Gálvez (2008), one way to help establish the relationship between Green Logistics and Reverse Logistics is to cite the definitions of both practices referenced academically and/or by practitioners. The fact that an explicit definition of Green Logistics is lacking confirms what Murphy and Poist (2003) state about the limited literature on this practice. This limitation includes the absence of a formal definition of the term Green Logistics.

For his part, Soto (2005) indicates that Green Logistics pursues objectives such as reuse of containers, recycling packaging materials, redesigning packaging, using fewer materials, and reducing energy consumption and pollution related to product transportation.

Finally, we can say that Green Logistics is more related to traditional logistics than to Reverse Logistics; this relationship occurs when the environmental impact during the development of traditional logistics is measured, and proposals arise from this measurement seeking to reduce that impact. Achieving this would allow Green Logistics to help traditional logistics complete its tasks efficiently according to the environmental criteria sought.

Regarding its relationship with Reverse Logistics, the following is presented:

1. They are mutually exclusive processes.

2. Green logistics proposes the reuse of containers as well as the recycling of packaging or packaging materials; these proposals are activities identified within Reverse Logistics.

3. Green Logistics poses, as an activity, the search for redesign to minimize material consumption both in the final product and its packaging, and one of the results obtained from developing Reverse Logistics practice is the generation of such information. It could be said that Reverse Logistics provides this information to Green Logistics for redesign aimed at minimizing material consumption and packaging. (León, et al., 2008).

2.4 Classification of Reverse Logistics for returned or returned products

Regarding classification for returned or return products in reverse logistics and using the analysis conducted by Bei, W. and Linyan, S. (2005), we find that there are all types of product categories related to the reverse logistics system, such as consumer or industrial goods, construction waste, household waste, packaging, distribution items, production by-products, electronic equipment, electronic devices, etc. (See Table 1), a general classification is offered of returned or return products that frequently occur considering the reasons for return and product varieties.

We can highlight the most important and representative elements: handling of goods, products, packaging, and containers, reduction at source, that is, through the product life cycle we must employ and use tools capable of obtaining the minimum possible amount of waste, debris, and non-recyclable or unrecoverable materials. It is a new environmental commitment in the supply chain which fosters the development of cleaner production (or service) aligned with better environmental practices and production.

3. Reverse Logistics and its relationship with waste management through supply chain

Since reverse logistics is a relatively new research area in the literature, it may also be found under other terms such as return logistics, inverted logistics, reverse distribution, and retro logistics. It is important to note that many people confuse the terms reverse logistics and waste management. The latter mainly refers to the collection and processing of products or materials that are disposed of. When referring to the term "waste," legal consequences may arise, such as regulations governing the import/export of waste, whereas reverse logistics focuses on the flows (both forward and reverse) where there is some value to be recovered from the products and materials, which can then be reintroduced into a new production chain (Maquera, 2012).

Therefore, based on a company's functionality, two types of reverse logistics can be distinguished:

1. Reverse logistics for waste: This involves the collection, recycling, and treatment of waste generated by the final product after it has

Table 1. Classification of Reverse logistics (RL)

Classification of RL	Driving forces	Processes	Referenced Product-Cases	
Manufacturing yields : Surplus raw material Production waste	Economic Legislation	Recycling/ Reuse Remanufacturing	Ferrous scrap/ Pharmaceutical materials	Johnson, P. F. (1998). Managing Value in Reverse Logistics Systems, Logistics and Transportation Review, 34, 3, pags. 217-227 Simon M G, Bee G, Moore P et at,(2001). Modeling of the Life Cycle of Products with Date Acquisition Features, Computers in Industry, 45, pags., 111-122
Distribution returns: Product recalls due to safety/healthy issues Adjustment of outdated/obsolete stock B2B commercial returns (products)	Economy (legislation)	Recycling/ Repair/ Resale/ Remanufacturing	Consumer Monitor-Industrial goods	Krikke, H. R., Van Harten, A. & Schuur, P. C.(1999) Business Case Roteb: Recovery Strategies for Monitors, Computers & Industrial Engineering, 36, 4, pags, 739-757 Fleischmann, M. (2001).Reverse Logistics Network Structures and Design, ERIM Report Series Research in Management, ERS-2001-52-LIS, pags, 1-21 Bartel T., (1995).Recycling Program for Toner Cartridges and OpticalPhotoconductors, Proceedings IEEE Symposium on Electronics and the Environment, Orlando Florida, pags, 225-228
Returns after distribution B2C Used distribution items	Economy (legislation)	Reuse/ Recycling	Pallets/ Packaging	Anderson, S., Browne, & M., Allen, J. (1999). Logistics Implications of the UK Packaging Waste Regulations, International Journal of Logistics: research and Applications, 2, 2 (1999), 129-145 Duhaime, R., Riope,l. D., & Langevin, A. (2000). Value Analysis and Optimization of Reusable Containers at Canada Post, Interface, 31, 3, pags, 3-15
Commercial returns from customers Money-back guarantee for unsatisfactory new products.	Economy (legislation)	Resale/ Reuse	Clothing/ Commercial goods	De Brito, M. P., & Dekker, R. (2003). Modeling Product Returns in Inventory Control – An Empirical Validation of General Assumptions, International Journal of Production Economics, 81-82, pags, 225-241 Meyer, H. (1999). Many Happy Returns, The Journal of Business Strategy, 20, 4, pags,27-31
Customer service returns Upgrade/repair requests	Economy (legislation)	Repair/ Recovery	Machines/ Circuit boards	Klausner, M., & Grimm, W. M, Hendrickson, (1998).Reuse of Electric Motors in Consumer Products, Design and Analysis of An Electronic Date Log, Journal of Industrial Ecology, 2, 2, pags, 89-102 Diaz A, & Fu M C,(1997) Models for Multi-echelon Repairable Item Inventory Systems with Limited Repair Capacity, European Journal of Operational Research, 97, 3, pags, 480-492
Post-use returns from customers End-of-use returns End-of-life returns	Economy (legislation)	Remanufacturing/ Recycling	Electronic device/ Sand/ Batteries/ Carpet	Simon, M. G, Bee, G., Moore, P., et at,.(2001). Modeling of the Life Cycle of Products with Date Acquisition Features, Computers in Industry, 45, (2001), 111-122 Barros, A. I., Dekker, R. & Scholten, V. (1998). A Two-level Network for Recycling Sand: A Case Study, European Journal of Operational Research, 110, 2 pags., 199-215 Louwers, D., Kip, B. J., Peter,s E. et at,(1999) A facility Location Allocation Model for Reusing Carpet Materials, Computers & Industrial Engineering, 36, 4, pags, 1-15

Source: Own elaboration, adapted based on Bei, W. and Linyan, S. (2005:23) been commercialized. The aim is to reduce the environmental impact of this waste and to fulfill the logistical objective of reusing it to generate value again, whether as raw materials, spare parts, etc.

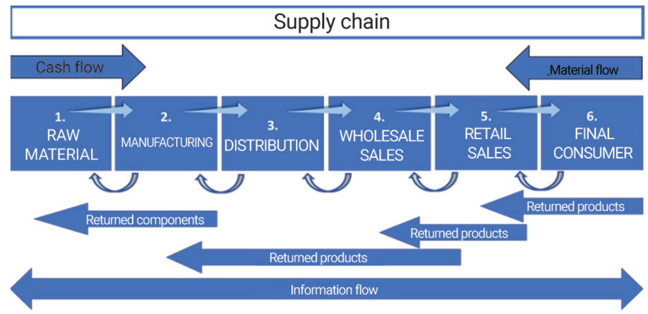
2. Reverse logistics for returns: This involves returning the product from the final customer back to the point of origin. This may occur due to customer dissatisfaction, delivery errors, defective products, among other reasons. Specifically, reverse logistics for returns is most closely related to the operations of e-commerce[1] platforms. ECOMMERCE. (2021).

In this sense, reverse logistics aligns with waste management (e.g., packaging, containers, and hazardous waste) through the most commonly used reprocessing options in the industry, such as remanufacturing and recycling (Dowlatshahi, 2005). Remanufacturing refers to the process in which used products are restored to a like-new condition, while recycling is a process that recovers materials from used products without preserving the identity of their components. These reprocessing options link reverse logistics with sustainable development, assuming that society should make full use of the value contained in products (de Brito and Dekker, 2004).

Furthermore, according to the guidelines from the American Production and Inventory Control Society (APICS) in their Certified in Logistics, Transportation and Distribution (CLTD) program, a complete supply chain must include a reverse logistics process dedicated to returning, repairing, remanufacturing, and/or recycling products and materials (APICS, 2019). This process begins with the planning and control of the movement of goods from the point of consumption back to the point of origin for disposition into any of the aforementioned processes.

This APICS proposal is considered comprehensive as it provides a solid conceptualization and analysis of current information, linking the concept of the supply chain with reverse logistics, giving relevance to the latter, and indicating the minimum aspects of the process. It also makes clear that there are simple, medium, and highly complex schemes depending on the size of the organization in question, as each has different transformation and manufacturing processes. Moreover, APICS serves as a guide for human capital development and policy formation in reverse logistics for organizations. (See Figure 1).

Figure 1. Flow of a supply chain with reverse logistics



Source: APICS CSCP Learning System (2016)

It is important to mention that there are different waste transformation processes:

- Return of products rejected by the final customer or surplus inventory at the end of their life cycle.
- Return for reuse of containers, packaging, and handling units for their reconditioning and reuse.
- Reuse of materials in processes where they can be used again in the same production cycle.
- Reconditioning of defective rejected products, which can be restored for resale. Waste and residue management sent to recycling facilities and specialized centers due to their hazardous nature.
- Waste management for destruction and final disposal.
- Management of substitute recycled materials that reduce the use of current materials, which implies innovation and improvements in product design. (Reverse Logistics Association, 2002).

Understanding these different transformation processes, it is necessary to specify that this paper focuses solely on the return for reuse of containers, packaging, and handling units for their reconditioning and reuse, as this process is particularly relevant to the authors due to the environmental impact of not carrying it out.

[1]Worldwide, buyers return an average of US$642.6 billion in merchandise each year, which significantly reduces profit margins and increases logistics costs for companies. In this regard, the reverse logistics process and its associated transportation and other costs related to order returns present a complex challenge for 83% of retailers in Latin America. (ECOMMERCE, 2021).

Regarding the functionality of reverse logistics in companies, it is divided into three aspects known as the Triple Bottom Line (TBL). This approach is used in sustainable businesses to measure the economic, social, and environmental impact of an organization's activities with the goal of delivering value to shareholders (APICS, 2019).

The actions implemented under the TBL are directly related to reverse logistics since the economic, environmental, and social solutions generated under this ideology often involve savings, recycling, and the reuse of materials, inputs, and finished products which is precisely the goal of Reverse Logistics within companies.

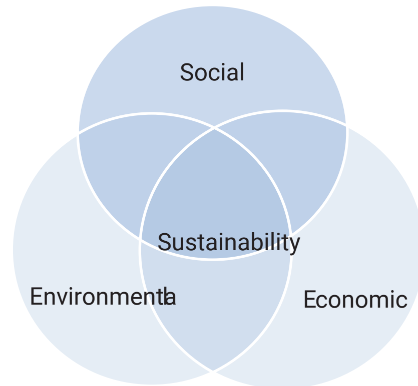
According to the TBL, reverse logistics functions in companies are divided as follows:

1. Economic: It involves capital savings and product improvement based on cannibalization, recovery of value from containers, packaging, and recycling units. All of this is driven by the implementation of new technologies, investment in eco-friendly processes aimed at resource efficiency and cost reduction, and the implementation of environmental policies that include energy savings in buildings and transport, reduction of carbon emissions, reduction of office waste (e.g., paper), and promotion of interactions with sustainable companies and the consumption of eco-friendly products by both clients and suppliers (APICS, 2019).

2. Environmental: Derived from the protection of health and the environment, and considerations for waste management and processing. It is constantly monitored by environmental organizations focused on the supply chain and its use in manufacturing environmental processes and the movement of raw materials and finished goods (APICS, 2019).

3. Social responsibility: Driven by non-governmental organizations and consumers empowered by their purchasing power, seeking safer and more environmentally friendly products. Socially oriented environmental protection organizations are responsible for creating policies and programs that contribute to society. These associations aim to create a sense of social responsibility by promoting the successes and failures of labor practices within the company. An example of this is the "Socially Responsible Company" label awarded through good environmental labor practices (APICS, 2019). (See Figure 2)

Figure 2. TBL Diagram



Source: APICS CLTD Learning System, (2019).

Regarding the implementation of the process and according to the Reverse Logistics Association, which estimates that in 2013 the total volume of returned products ranged between US$150 and US$200 billion, another report from the Aberdeen Group an organization dedicated to collecting and analyzing consumer behavior data in more than 200 sectors states that the average company invests between nine and fourteen percent of its total revenue in the reverse logistics process. This indicates that practicing reverse logistics does not represent a high cost and that its implementation is feasible within any company. However, the most surprising data point is that forty-five percent of existing companies do not implement a reverse logistics strategy in a systematic and efficient manner for the return of products (APICS, 2019). From this, it can be concluded that even today, many companies still lack awareness of the benefits and advantages that reverse logistics offers within the supply chain.

4. Reverse Logistics in the context of COVID-19

Following the pandemic caused by the SARS-CoV-2 virus, several sectors of society if not all have been affected, and logistics within companies has been no exception. However, not all consequences have been negative; in fact, logistics has taken on a significant role due to the skyrocketing growth of online sales which, despite offering benefits to society by helping avoid virus spread, has left reverse logistics with the difficult task of readapting its usual practices to the standards and protocols that adapting to the "new normal" will require. Nevertheless, due to the increase in waste (e.g., packaging and containers), raising awareness among companies and motivating them to implement reverse logistics as a core activity plays a very important role in the future of our society, especially in terms of environmental impact, and also positively affects economic and social aspects. Below are some relevant statistical data reported by several authors:

Figures indicate that during the pandemic, approximately seventy-five percent of the plastic used for manufacturing face masks, gloves, and hand sanitizer bottles will become waste that will seriously harm both ecology and the economy (UNCTAD, 2020).

As for the everyday use of plastic for packaging during the pandemic, it is estimated that less than ten percent will be recycled, and more than seventy percent will directly harm the environment, remaining in streets and oceans. It is said that the SARS-CoV-2 virus can survive on plastic surfaces for up to three days, which contributed to increased use of single-use plastics, resulting in a spike in packaging and wrapping waste (UN, 2021).

The increase in online purchases has reached nearly ninety percent and has caused a corresponding rise in solid waste generation (cardboard boxes, packing materials, Styrofoam protectors, plastic, and other materials with high environmental costs), ranging between forty and sixty percent (AMVO, 2020).

The rise in online purchases has also led to a proportional increase in returns; due to logistical blockages between countries and internally, reverse logistics has been disrupted, which could cause a future bottleneck as supply chains are gradually reopened. Some companies have even opted to temporarily suspend certain return policies as an economic and health measure (Kirve, 2020).

New health protocols have been created within the supply chain to prevent the spread of the virus, such as disinfecting and cleaning returned items. Warehouses are spaces where worker safety is of utmost importance, and government safety measures and recommendations must be followed with the corresponding procedures established. There has been a reassignment of store workers to warehouses to efficiently manage the workload. This has affected the efficiency of reverse logistics, especially for companies lacking economic or technological resources to meet health measures or to replace personnel with technology in their supply chain processes, according to reverse logistics firm goTRG (goTRG, 2021).

There have been cases where companies that encouraged the reuse of bottles and plastic bags had to suspend these practices. One example is Starbucks, which, just one week after the first U.S. case of SARS-CoV-2 was confirmed, temporarily banned the use of reusable coffee mugs and tumblers (Plastics Technology México, 2020).

In light of these developments, it is necessary to generate and propose new readaptation methods that increase the adoption and reactivation of reverse logistics. It is crucial to create proposals whether public or private (from governments or chambers of commerce, for example) that encourage small, medium, and large enterprises to apply sustainable methods that have less environmental impact, taking into account the scenario of the "new normal" and its sanitary consequences.

Some processes are beginning to be proposed by large companies and global logistics leaders. While not all procedures can be applied or adapted by all businesses due to economic or other factors, it is important to consider them as starting points for strategies that promote good reverse logistics practices without compromising the health of personnel executing these processes. Below are some of the procedures implemented:

- Following government policies: It is important that the population and businesses are informed and able to implement the public policies that government agencies recommend to prevent the spread of COVID-19 (Kirve, 2020).

- Creating more flexible return policies: This helps avoid return congestion. By extending the return window, pressure to immediately return products is reduced, allowing items to arrive gradually. Some policies, like those implemented by Walmart and Amazon, even allow the customer to keep the product while still receiving a refund (Kirve, 2020).

- Hiring third-party logistics companies (3PL): These firms offer reverse logistics services to both large and small businesses. They handle transportation and storage challenges, manage returns and route them to warehouses or replenishment centers, oversee inventory and supply chains, process customer refunds, and more (goTRG, 2021).

• Frictionless returns: This process uses software to automate exchanges and returns, providing customers with a seamless self-service experience or allowing them to choose among several convenient options to return items through applications like Happy Returns (Happy Returns, 2021).

• Adopting a fully integrated e-commerce platform, as Amazon does, which—through this type of system allows the management of terminals on a single store server, reducing contact between individuals and minimizing returns due to "wrong size or product" (NCR, 2021).

For this to be possible, it is necessary to raise awareness among business owners, implement training programs for human resources in the supply chain, and foster a social commitment from higher education institutions to provide knowledge on the topic and train professionals with sufficient competencies to perform in these contexts. Furthermore, governments must support by financing reverse logistics programs and by promoting and encouraging social, economic, and environmental development commitments, as well as enforcing the international and national agreements and treaties already in place.

It should be remembered that reverse logistics for packaging and wrapping waste during COVID-19 is a complex phenomenon that requires collaboration among different sectors to move forward.

5. Conclusions

Based on the literature review, it can be concluded that reverse logistics is gaining significant importance in today's world. Currently, companies are facing new challenges related to reverse logistics during the COVID-19 crisis, including high uncertainty regarding supply time, quantity, and quality.

Additionally, the increase in the amount of waste, returned or remanufactured products, and other reverse flows is creating a new issue—one that years ago may not have been considered as important, or if it was, not with the same level of relevance. This growing importance is prompting the publication of various laws or decrees by different authorities (local, national, or supranational) and the emergence of numerous companies seeking to address the challenges that arise.

For this reason, it is essential to continue researching processes, especially those related to the management of products or materials that can re-enter the supply chain and have associated environmental impacts, which represent a challenge for companies. To address these challenges, strategies like reverse logistics can be implemented, which involve a series of operations to recover value from solid waste or to dispose of it appropriately. It will be necessary to redesign and develop proposals that align with health protocols, customs, and practices that will be implemented in the "new normal." These proposals should enable, promote, and encourage companies to adopt reverse logistics for packaging and wrapping, combining existing regulations with current needs.

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RESEARCH

Mining in Sonora: a key component in achieving the 17 sustainable development goals (SDGs) of the 2030 Agenda

La minería sonorense, pieza clave en el cumplimiento de los 17 Objetivos del Desarrollo Sostenible (ODS), en la agenda 2030

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Abstract

In recent years, the concept of sustainable development (SD) has been strengthened, since its first description adopted by the Bruntland Commission in 1987; Recently, the 195 Members of the United Nations (UN) approved a document entitled "Transforming Our World: The 2030 Agenda, for Sustainable Development (ODS)", which will be in force during the years 2015 to 2030. Economic, social and environmental growth and development are impacted by various economic activities such as mining, and these not only locally, they transcend borders, clearly these impacts can be used to create new infrastructures, new technologies and opportunities in relationship with the workforce, highlighting that this industry has the opportunity and the necessary potential to contribute positively to the achievement of the 17 Sustainable Development Goals (SDG), in the new 2030 agenda; The objective of this article is to describe and analyze the impact of the 17 SDGs, from the "Economic Development" section or section, specifically SDG 8, 9 and 12, in gold mining in the state of Sonora, with emphasis on the region of Caborca, Sonora, Mexico, in the period from 2008 to 2018.

Keywords: environmental economics, regional development, mining, 17 SDG 20-30 agenda.

JEL codes: L72, Q01, Q32 and Q43

Resumen

En los últimos años, el concepto de desarrollo sostenible (DS), se ha fortalecido, desde su primera descripción adoptada por la Comisión Bruntland en el año 1987; recientemente los 195 Miembros de la Organización de las Naciones Unidas (ONU), aprobaron un documento titulado "Transformar Nuestro Mundo: La Agenda 2030, para el Desarrollo Sostenible (ODS)", los cuales estarán vigentes durante los años del 2015 al 2030.

El crecimiento y desarrollo económico, social y ambiental, se ven impactados por varias actividades

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económicas como lo es la minería, y estos no solo en lo local, estos trascienden fronteras, claramente dichos impactos pueden aprovecharse para crear nuevas infraestructuras, nuevas tecnologías y oportunidades en relación con la fuerza de trabajo, destacando que esta industria tiene la oportunidad y el potencial necesario para contribuir positivamente en el logro de los 17 Objetivos del Desarrollo Sostenible (ODS), en la nueva agenda 2030; el objetivo de este artículo se centran en describir y analizar el impacto de los 17 ODS, desde el apartado o sección "Desarrollo Económico", específicamente los ODS 8, 9 y 12, en la minería de oro del estado de Sonora, con énfasis en la región de Caborca, Sonora, México, en el período de 2008 al 2018.

Palabras claves: economía ambiental, desarrollo sostenible, minería, 17 ODS en la Agenda 20-30.

Códigos JEL: L72, Q01, Q32 y Q43

Introduction

Over the years, society and science have joined forces to raise awareness and promote actions that help mitigate and reduce the effects of climate change on our planet. This has led to deep reflection and debate around the study of topics linking economic activities and the environment. This relationship is based on the argument that the origin of environmental problems lies in the growth of any economic activity, resulting in pollutant emissions. Mining, as a primary economic activity, generates a high demand for natural resources, most of which are non-renewable, affecting environmental assets. The production of goods and/or services inevitably impacts environmental quality. (Escalante R., et al., 2005). Hence, the importance of studying the relationship between economic activities and the sustainable development of a region becomes a global priority, reflected in the new 2030 Agenda and its 17 Sustainable Development Goals (SDGs).

1. Mining and its role in achieving the 17 SDGs of the 2030 Agenda.

One of the most internationally prominent industrial sectors is undoubtedly mining. This economic activity focuses on the extraction of metals from the earth on a medium or large scale. Given that these resources are non-renewable, controversies arise, arguing that mining contradicts the principles of sustainability. However, mining significantly contributes to the prosperity and well-being of both current and future generations. (Orellana J., 2016). A proposal for achieving Sustainable Development (SD) within the mining context was put forward by Jenkins and Yakovleva in 2006. They argue that sustainability is attainable if three key aspects are met:

1. *The depletion of mineral resources, as these are extracted, they can be compensated by new capital uses that benefit both present and future generation.*
2. *Resource exhaustion should not pose a future problem, many non-combustible metals and minerals can be recovered through recycling and reused.*
3. *The discovery of new mineral deposits combined with technological advancements, this enables improved recovery process, making it possible to apply sustainable development to and from the mining industry (Jenkins et al., 2006).*

Some actions supporting the achievement of Sustainable Development and the SDGs within the "2030 Agenda" highlight the importance of mining in the United Nations' (UN) renewed commitment to reduce the carbon footprint and carbon dioxide (CO_2) emissions, as well as other greenhouse gases contributing to global climate change. This reinforces a global action plan for social inclusion, environmental sustainability, and economic development. The participation of the mining sector is vital for achieving the 17 SDGs. Therefore, several international protocols and documents have been developed to strengthen sustainable mining, such as:

- *The "Proyecto Minería Minerales y Desarrollo Sostenible" (MMDS) project, which outlines compliance with commitments established in Agenda 21, defining short, medium, and long-term objectives for the sector.*
- *The Regional Seminar"Minería para un futuro bajo en Carbono: Oportunidades y desafíos para el Desarrollo Sostenible", held on June 4th and 5th in 2018, at CEPAL headquarters in Santiago, Chile, emphasized the connection between the mining sector and climate change challenges. It*

recognized mining as a fundamental element in mitigating greenhouse gas emissions associated with climate change.

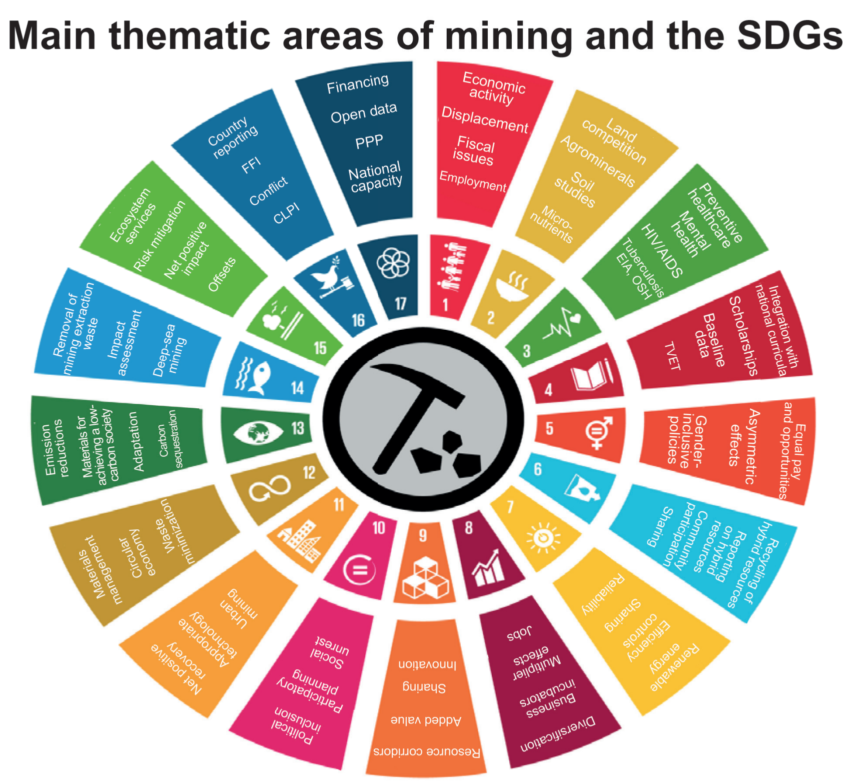
- *The Foro Económico Mundial, in collaboration with the Programa de las Naciones Unidas para el Medio Ambiente (PNUMA), the Columbia Center on Sustainable Investment, and the Red de Soluciones para el Desarrollo Sostenible, affirms that large-scale mining has the potential to pay a critical and transformative role in supporting the SDGs through the adoption of best practices.*

The final compilation of these initiatives is the report "Cartografía de la minería en relación con los ODS", which highlights the local, regional, and national impact of mining on development and economic growth. It suggests mining can be leveraged to create new infrastructure, technologies, and workforce opportunities. This approach proposes that mining operations should identify their opportunities, responsibilities, and roles within the framework of the 17 SDGs. Increasing collaboration between governments, communities, civil society, and other stakeholders is essential to achieve the SDGs. This proposal, summarized in an atlas, serves as a model for the mining sector and aims to achieve the following outcomes:

1. *Improve understanding of the relationship between mining and the SDGs.*
2. *Raise awareness about the opportunities and challenges that the SDGs present to mining and its stakeholders, including how to address them in efforts to reduce the carbon footprint.*
3. *Establish dialogue and collaboration among multiple stakeholders to accomplish the SDGs.*

According to PNUMA, most materials extracted through mining serve as raw inputs for countless industrial production processes essential for creating new technologies or enhancing existing ones. It is acknowledged that mining, as an economic activity, can influence the achievement of the 17 SDGs either positively or negatively. It facilitates opportunities for decent employment, business development, and increased public revenue in local communities. This close relationship between mining and the SDGs is illustrated in a visual developed by the UN, showing the impact of each goal on mining activities. Implementing these strategies can help reduce both the carbon and water footprint of the mining industry.

Illustration 1. Thematic objectives of the 17 sustainable development goals



Source: Mapping of mining in relation of the Sustainable Development Goals. Recovered from: https://irpcdn.multiscreensite.com/be6d1d56/files/uploaded/Mapping_Mining_SDGs_An_Atlas-Spanish-FINAL-cover.pdf, Retrieved on June 5th, 2019.

Mining has made considerable advances in mitigating and managing the reduction of Carbon Dioxide (CO_2), as well as in addressing the intrinsic effects and risks of this activity. These actions have helped reduce environmental degradation, population displacement, and exacerbation of economic inequalities through improved sustainability practices across the three pillars of sustainable development, such as: managing environmental and social consequences, protecting workers' health, ensuring energy efficiency, incorporating new environmentally friendly technologies, respecting and supporting human rights. These adaptations have shifted mining's contribution positively toward achieving the 17 SDGs, highlighting that the success of these actions, measures, and opportunities will entirely depend on:

> *"the social, political, and economic context, as well as the mineral resource in question, during its various phases of exploration, development, extraction, or closure, and on contributions made by local communities and other stakeholders through dialogue".* Cepal, Minería para un futuro bajo en Carbono, 2020.

The 17 SDGs are primarily described within the three spheres of sustainable development as follows:

A. Environmental sustainability: *This group encompasses all mining activities that typically affect the land, water, climate, flora, and fauna — resources on which we depend. The first conjunction of goals appears between SDG 6 (Clean Water and Sanitation) and SDG 15 (Life on Land), because mine construction requires access to land or subsoil as well as water resources, which impacts the land and natural resources. The next conjunction is between SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action): the large amounts of energy required by mining, and the generation of dust, must be measured and provide opportunities to increase energy efficiency.*

B. Social inclusion *This section considers the significant positive and negative consequences mining can have on local communities by generating opportunities and challenges related to livelihoods and human rights. The relationship among SDG 1 (No Poverty), SDG 5 (Gender Equality), and SDG 10 (Reduced Inequalities) describes mining's contribution as a large-scale generator of business opportunities, local employment, and substantial revenues via taxes, royalties, and dividends, which governments can invest in economic or social development. SDG 16 (Peace, Justice, and Strong Institutions) mentions how mining can support building peaceful societies and consolidating the rule of law by preventing and resolving conflicts between companies and local communities.*

C. Economic development: *This section analyzes mining's impact on economic potential at local, regional, and national levels, which can be leveraged to create new infrastructure, technologies, and workforce opportunities. SDG 8 (Decent Work and Economic Growth) focuses on generating new economic opportunities for citizens and developing service providers or new local economies linked to the mine. SDG 9 (Industry, Innovation, and Infrastructure) and SDG 12 (Responsible Consumption and Production) show that mining can boost economic diversification and development through its direct and indirect economic benefits and by fostering the construction of new infrastructure for communication, transport, water, and energy supply.*

For Mexico, the mining sector with the greatest international projection includes metallic minerals such as gold, silver, and copper, generating the highest revenues with an income of 153,044.3 million pesos, representing 80.5% of the national total (Instituto Nacional de Estadística y Geografía - INEGI, 2014). Table 1 shows the number of kilograms produced by this group of Mexican minerals over the last 12 years.

Table 1. Mining production expressed in kilograms (kg) for the years 2006, 2010, and 2018 in Mexico

	2006	2010	**2018**
Gold	38,961.31	79,375.50	141,140.00
Silver	2,969,845.00	4,410,749.00	7,243,250.00
Copper	334,129,000.00	270,136,000.00	677,161,000.15

Source: Own elaboration based on data from, Servicio Geológico Mexicano, SGM. (2007, 2011, and 2019 versions).

Part of these productivity advances in Mexican mining are due to modifications and the use of new mining technologies, mainly open-pit mining, which have allowed the exploitation of large land deposits simultaneously. This shift has led to industrialized mining focused on large-scale metal extraction, incorporating heap leaching and the use of metallurgical technologies with lower costs and higher yields (Cárdenas J., 2013). Open-pit mining has notable environmental impacts, directly affecting flora, fauna, and constant emissions of gases and dust. Water is the most alarming factor, as the northwestern states where these mega-projects are located have the lowest water availability, less than 30% compared to the rest of the national territory, leading to an uncertain future (Cárdenas J., 2013). This new "large-scale mining, industrial mining, or mega-mining" is not defined in the Mining Law or its regulations; only small and medium capacities are defined. It could be said that mining with a capacity greater than 2,000 tons of daily extraction is mega-mining (Armendáriz, E., 2016), (Mining Law Regulation, art. 9-II). Large mining companies play a fundamental role in achieving the 17 SDGs and significantly reducing CO_2 emissions.

2. Economic development goals in the 2030 Agenda: an approach to compliance in Sonoran mining

As mentioned earlier, for descriptive purposes, this article will analyze the characteristics and approaches of the economic sector or economic development within sustainable development (SD), incorporated into the targets of the 17 SDGs, considering data from Sonoran gold mining in the following areas:

- Contribution to the state GDP.
- Annual extractive production.
- Generation of direct employment at the state level.
- Creation of supply chains.
- Number of participating municipalities.

These are incorporated into the achievement of three goals: SDG 8, SDG 9, and SDG 12, defined and developed as follows:

I. SDG 8: decent work and economic growth: *this goal aims to create the necessary conditions for sustainable and inclusive economic growth and job creation. It focuses on eliminating child labor, protecting labor rights, and promoting economic growth by guaranteeing opportunities and decent work for all.*

The contribution of Sonoran mining to this goal can be analyzed and measured by various data, one being the increase in direct employment generation due to the growth of the mining industry in Sonora. Each year, more and better jobs are created; in 2016, the direct workforce was 15,988, and two years later, it exceeded 20,000, with over 80,000 indirect jobs, according to information published by the Secretaría de Economía del Gobierno de Sonora (SE Sonora) in 2019.

Another measure of economic growth is the Gross Domestic Product (GDP), which shows a considerable increase. In 2008, mining contributed 4% to the state GDP, rising to 17% in 2018. For the same year, the extractive volume of gold reached nearly 40,000 kilograms, with a production value slightly over 32,393 million pesos according to SGM figures. This value is also highlighted in an article by the Observatorio de Conflictos Minero de América Latina (OCMAL): “Oro en Sonora: Mineras muy ricas, pueblos muy pobres”, stating that the kilograms of gold extracted by Sonoran mining projects in 2018 are equivalent in weight to 17.7 Ford F-150 pickup trucks, fully made of solid gold with a purity no less than 98.7% (Gutiérrez F., 2019).

Table 2 shows the increase in direct workforce and GDP contributions at three different time points, based on information from Bracamontes A. et al. (1997) and SGM 2017 for Sonora.

Table 2. Economic growth contributed by mining in Sonora in the years 1970, 1990, and 2016.

	1970	1990	2016
State GDP contribution	4.6%	8.7%	17%
Direct labor force	4,266	13,486	15,988

Source: Own elaboration based on data provided by Bracamontes A. (1997), and the 2017 statistical yearbook of the SGM.

Without a doubt, a paradigm shift that reinforces the achievement of this goal is the hiring and participation of women in Sonoran mining. For example, the gold-producing mining unit “La Herradura,” located in the municipality of Caborca, had 33 % female labor in its production process in 2018, totaling 266 women (Fresnillo Plc, 2019).

Table 3 lists all the municipalities in Sonora that participated in gold extraction between 2008 and 2018, which gives a clearer idea of the progress in Sonoran mining productivity. The data presented come from the Instituto Nacional de Estadística Geografía (INEGI), the Servicio Geológico Mexicano (SGM), and the Cámara Minera de México

(CAMIMEX), including extraction contributions, production volume in kilograms, and production value.

Table 3. Total participation of Sonoran municipalities in gold extraction, total production in kilograms, and production value in thousands of USD (2008-2018).

Year	Total municipalities	Total production in kg	Production value in thousands of USD
2008	9	12,229.60	$273,938.17
2009	10	14,630.40	$410,031.98
2010	10	17,561.50	$549,262.13
2011	10	22,539.10	$887,484.49
2012	8	27,560.00	$1,524,916.75
2013	9	30,002.90	$1,609,763.26
2014	12	35,364.10	$1,604,294.55
2015	12	34,926.00	$1,421,127.16
2016	9	49,591.50	$1,588,593.74
2017	13	47,412.30	$1,902,392.37
2018	11	42,290.40	$1,767,582.25

Source: Own elaboration based on SGM and CAMIMEX yearbooks (2008-2018) for Sonora.

Table 4 shows the 13 municipalities that participated in gold extraction in 2019, with a total of 47,412.3 kg.

Table 4. Annual contribution by municipality (kg) for 2019.

Municipality	Production in kg
Caborca	20,796.60
Sahuaripa	8,406.90
Altar	6,128.00
Santa Ana	3,125.00
Cucurpe	3, 579.00
Banamichi	1,513.00
Cananea	1,439.40
La Colorada	1,147.00
Magdalena	693.10
Álamos	6,218.00
Santa Ana	303.00
Nacozari de García	272.80
Hermosillo	9.10

Source: Own elaboration based on data from SGM 2019 and CAMIMEX 2019 yearbooks.

It can be observed that Caborca is the municipality with the highest share of gold production, accounting for 44% of the state total. It has three mining units operated by the Fresnillo Plc group. Gold production in this municipality increased from 6,084.60 kg in 2008 to nearly triple that amount in just 10 years. Table 5 presents these values for the 2008–2018 period.

Table 5. Gold extraction productivity for the municipality of Caborca, Sonora (2008-2018).

Year	Production in kg
2008	6,084.60
2009	6,810.60
2010	8,115.60
2011	12,446.00
2012	15,314.00
2013	15,160.00
2014	15,322.10
2015	15,532.20
2016	25,257.00
2017	20,796.00
2018	19,293.90

Source: Own elaboration based on data from the CAMIMEX statistical yearbook (2008-2018).. Retrieved from: https://www.economia.gob.mx/files/comunidad_negocios/informacion_sectorial/mineria/anuario_2009.pdf

II. SDG 9: Industry, innovation, and infrastructure*, this goal refers to transportation, water and energy supply infras tructure, technology, and communications—generating dynamic and resilient societies.*

The degree to which the mining industry aligns with this goal can be seen primarily in its land access to the main mining unit, "La Herradura." This mine is the most important at the state and national level, as it is the top gold producer. "La Herradura" is located 120 km northwest of the city, near the municipality of Caborca. There are multiple haulage routes, with the main provider being the Sonoran company Construplan, which holds a 7-year contract to transport more than 3 million tons per month. In addition, 1,500 indirect jobs have been created, tied to local suppliers from the municipality.

In the Manifiesto de Impacto Ambiental (MIA), repared by the mining group in 2008 for the approval of its expansion, it is noted that water management and studies of surface and underground resources were conducted by the National Water Commission (CNA), the responsible administrative body. The project, listed as "Cuenca Río Sonoyta 2," covers an area of 274,340 km², defined as the base for operations. It includes an estimated area of 1,167 hectares, divided into processing plants, transport and haulage roads, leaching pads, explosives warehouses, workshops and fuel stations, offices, and parking lots. Much of the municipality's development is partly due to the contributions from the "Fondo minero" (Fondo para el Desarrollo Regional Sustentable de Estado y Municipios Mineros). Since 2014, economic contributions—amounting to millions of pesos—have been invested as part of efforts to remediate the environmental and social impacts in the region where the mine operates. An example of this is the list of projects approved for the municipality's improvement during the 2019 fiscal year, as shown in Table 6.

To meet SDG 9, the company Fresnillo Plc contributes and complies in the municipality of Caborca through statutes and regulations adapted to modern times and committed to CO_2 reduction. These objectives are published on public-access platforms as part of their move toward sustainable mining:

..."Fresnillo plc is a company dedicated to the exploration, extraction, and processing of minerals. It is committed to pollution prevention and seeks to ensure a safe and healthy environment for its employees, maintain good relationships with neighboring communities, comply with regulatory and legal requirements, and continuously improve our production processes through an integrated management system. As one of the leading precious metals companies, we strive to carry out all our operations in a sustainable manner. Our goal is to minimize the environmental impact of our operations throughout the entire life cycle of a mine by reducing the use of non-renewable resources and investing in conservation. Environmental stewardship is essential for the social acceptance of mining projects. We continuously monitor performance and management response to environmental challenges. Our operating philosophy is to manage environmental risk and mitigate our impact throughout the life cycle of a mine. The Group's environmental management systems cover the exploration, development, and operation phases of a mine, through to closure and rehabilitation. Throughout our long experience in the mining sector, we have identified five main environmental aspects in which our operations have an impact and thus require control and mitigation:

Energy: Reduce unit energy consumption.

Table 6. Projects approved by the Fondo Minero for fiscal year 2019. Expressed in Mexican pesos

Road paving improvement and/ or rehabilitation	Well rehabilitation/ hydraulic infrastructure	Public lighting rehabilitation	Educational infrastructure rehabilitation	Sports units/ Gardens rehabilitation
$2,616,193.00	1,409,398.84	$6,194,054.93	$4,145,075.00	$1,695,308.00
$8,176,365.00	$468,173.00	320,991.00		7,931,034.00
$7,020,116.00	$2,667,389.00	$356,822.00		5,387,938.00
$2,040,162.00	$881,127.00	$483,791.00		$5,679,914.00
$3,695,384.00	1,701,504.00			$6,842,878.00
$5,196,600.00	$3,334,546.00			33,920,628.00
1,975,624.00				4,551,718.40
$42,125,439.00				
42,931,366.00				
$26,290,270.00				
18,759,124.00				
$42,909,825.00				
$203,736,468.00	10,462,137.84	$7,355,658.93	$4,145,075.00	$66,009,418.40

Source: Own elaboration based on data from SEDATU, Retrieved from: https://www.gob.mx/sedatu/acciones-y-programas/fondo-minero-para-el-desarrollo-regional-sustentable

Water: Reduce the unit consumption of freshwater by reusing it.

Emissions: Contain dust and minimize CO_2 emissions from indirect energy sources.

Waste/hazardous materials: Maximize the reuse rate of hazardous materials and ensure proper containment …"

They also recently announced on their website that by 2020 and 2021, 40% of the energy used will come from clean energy sources (www.fresnillo.com)

III. SDG 12: Responsible consumption and production, *this goal highlights the importance of doing more and better with fewer resources, involving supply chains related to production and consumption worldwide.*

IV. One of the mining sector's top priorities today is producing more minerals while using fewer resources. This has been clearly demonstrated in the previous sections, where the annual increase in productivity in Sonora and specifically in the municipality of Caborca has been shown. This growth is supported by the local supply chain, developed through the efforts of Sonoran suppliers. These supply chains have been organized, certified, and integrated since 2014 into the Clúster Minero. At its inception, the cluster included 105 local and national suppliers; by 2019, that number had grown to 149 suppliers. Some of the current challenges faced by mining suppliers can be outlined in Illustration 2.

And this supply chain must support the constant and growing demand for minerals, due to their incorporation into various production processes. However, these advances and demands must now be aligned to achieve a low-carbon future by modifying current energy production and consumption patterns. This marks a starting point for mining companies seeking to harmonize their operations with the Sustainable Development Goals (SDGs), linking social inclusion, environmental sustainability, and economic development.

Another very important element that contributes to the achievement of this goal is the "Empresa Socialmente Responsable" (ESR) award, which has been granted to the Fresnillo Plc Group for more than 16 consecutive years by the Centro Mexicano

Illustration 2. Current challenges for companies regarding the supply chain

Source: "Liderazgo y diferenciación en la cadena de suministros" Retrieved from: https://www.esan.edu.pe/conexion/actualidad/2017/07/17/liderazgo-y-diferenciacion-en-la-cadena-de-suministros/ Retrieved on September 18th, 2019.

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Conclusions

Mining, from an analytical and economic perspective, has enabled the development of economic tools for preventing and addressing environmental impacts, thereby reducing the degradation caused by this productive activity. Since these impacts arise from production processes and the consumption of goods, it is necessary to balance environmental, economic, and social objectives. (Charles K, 2001). This much-needed balance for mitigating externalities is supported by various indicators, which are analyzed and presented from the perspective of environmental economics. These efforts align with the United Nations agreements reflected in the 2030 Agenda, which acknowledges the important role of mining in achieving these goals—particularly those aimed at reducing the carbon footprint, the water footprint, among others.

The challenge Mexico and our state face in meeting the 17 SDGs in the mining sector is becoming increasingly complex. Efforts must be intensified to promote greater participation and dialogue with other industrial sectors, governments, educational institutions, and local communities where mining operations are established. Several issues remain unresolved, such as: harmonizing mining income taxes due to recent changes in the management of the Mining Fund by the federal government. This fund should also be used to stimulate the local economy by integrating extracted minerals into local production chains. Another pending task for mining in Sonora is obtaining reliable data on greenhouse gas emissions generated by mining industries, to develop accurate scenarios and provide solutions for reducing the carbon footprint caused by high fossil fuel consumption.

Efforts should be directed toward achieving economic, environmental, and social development from the local to the national level, ensuring that the taxes generated by mining companies truly benefit mining communities in Sonora by fostering sustainable communities across all three spheres of sustainable development. As resource allocation becomes more decentralized and professionalized, it will be possible to establish stable, professional groups that serve as neutral spaces for dialogue, conflict resolution, and resource distribution—resources generated by taxes aimed at mitigating the externalities caused by Sonora's mining sector, which are so urgently needed.

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