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CIRCULARITY IN THE STEEL PACKAGING SECTOR: AN ANALYSIS OF THE MAIN BARRIERS AND OPPORTUNITIES

CIRCULARIDADE NO SETOR DE EMBALAGENS DE AÇO: UMA ANÁLISE DAS PRINCIPAIS BARREIRAS E OPORTUNIDADES

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ABSTRACT

Purpose: The aim of this study is to examine the map the life cycle of steel packaging, investigate the barriers and enablers to the adoption of circular practices in the steel packaging sector in Brazil.
Theoretical framework: The Consist of adoption of a circular model of production and consumption, in which post-consumer raw materials are reintegrated into their respective value chains.
Methodology/Approach: A literature review is combined with qualitative research involving key sector experts to examine how the Brazilian steel packaging sector can transition to a more circular value chain.
Findings: The results of research indicate that steel packaging has the potential to join a group of products with closed-loop production cycles and that steel can be recycled indefinitely without losing the original properties.
Research, practical & social implications: The study contributes by elucidating that complete recycling of post-use steel packaging, would obviate the necessity for extracting iron ore to produce new steel packaging.
Originality/ Value: The value of study it focused on the concepts of circular economy, emphasizing the reverse logistics pillar for materials in a closed loop, enabling the reintegration of materials at the beginning of their life cycle. It demonstrated that the technical characteristics of steel packaging within the value chain allow post-use material to be reintegrated at the chain's inception.
Keywords: Circular economy. Steel packaging. Circular supply chain. Barriers. Enablers.

RESUMO

Objetivo: O objetivo deste estudo é analisar map de valor do ciclo de vida das embalagens de aço, investigar as barreiras e os facilitadores para a adoção de práticas circulares no setor de embalagens de aço no Brasil.
Referencial Teórico: Consiste na adoção de um modelo circular de produção e consumo, em que as matérias-primas pós-consumo são reintegradas nas respectivas cadeias de valor.
Metodologia/Abordagem: Uma revisão da literatura, combinada com uma pesquisa qualitativa envolvendo os principais especialistas do sector para examinar como o sector brasileiro de embalagens de aço pode fazer a transição para uma cadeia de valor mais circular.
Resultados: Os resultados da investigação indicam que as embalagens de aço têm potencial para se juntarem a um grupo de produtos com ciclos de produção em circuito fechado já que o aço pode ser reciclado indefinidamente sem perder as propriedades originais.
Contribuições, implicações práticas e sociais: O estudo contribui para elucidar que a reciclagem de todas as embalagens de aço pós-uso evitaria a necessidade de extrair minério de ferro para produzir novas embalagens de aço.
Originalidade/Valor: O valor do estudo centrou-se nos conceitos da economia circular, enfatizando o pilar da logística inversa dos materiais em circuito fechado, permitindo a reintegração dos materiais no início do seu ciclo de vida. Demonstrou que as características técnicas das embalagens de aço dentro da cadeia de valor permitem que o material pós-uso seja reintegrado no início da cadeia.
Palavras-chave: Economia Circular, Embalagens de Aço, Cadeia Circular de Suprimentos, Cadeia de Valor, Barreiras, Habilitadores.

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1. INTRODUCTION

The circular economy (CE) represents a shift from the traditional linear sup-ply chain, which involves the extraction, transformation, and disposal of resources, to a model in which resources are extracted, transformed, distributed, used, recovered, and recycled (Langergraber et al., 2020). As described by Murray at al., (2017), the CE is an economic model that seeks to optimize ecosystem functioning and promote human well-being by conceiving and managing the planning, acquisition, production, reprocessing, and recycling of resources as an integrated process.

The transition to a CE requires a fundamental redesign of industrial systems, although the substitution of virgin materials with recycled materials is also recognized as a beneficial solution (Kopnina, 2021). In this context, the Ellen MacArthur Foundation has introduced the concept of a closed-loop or infinite cycle of materials, in which waste generated at the end of a product's life is reintegrated into the value chain as new primary or secondary materials, enabling more conscious resource use (EMF, 2016).

Some materials, such as metals and glass, can be recycled and/or reused repeatedly. Materials that meet these requirements are referred to as permanent, while those that do not are called non-permanent (Geueke et al., 2018). Steel can be recycled indefinitely without losing its original properties (AISI, 2021).

The growing focus on recycling, driven by the concept of an "infinite material cycle," has garnered attention from end consumers and the media. Many developed countries, such as those in Europe and North America, have enacted waste management laws (Moura et al., 2016). Brazil was the first country in Latin America to enact a law along these lines, Law 12,305, which established the National Solid Waste Policy (*Política Nacional de Resíduos Sólidos* - PNRS) in 2010. In response to this law, in 2012, the Brazilian Association of Steel Packaging (*Associação Brasileira de Embalagem de Aço* - ABEAÇO) created Prolata, a non-profit association aimed at managing solid waste policies for the steel packaging sector, to serve as the sectoral agreement manager (ABEAÇO, 2019).

The recycling rates for steel packaging in Brazil still lag behind those observed in other parts of the world. This is likely due to various barriers, such as the size of the country, low levels of consumer awareness, and, in particular, the high rate of informal systems. These factors hinder the incorporation of steel packaging into a CE and are referred to as barriers in this study. In contrast, factors that facilitate the incorporation of steel packaging into a CE are referred to as enablers.

This study, based on relevant academic literature and a qualitative research approach, aims to provide practical and theoretical contributions that substantiate explanations, increase knowledge, and add value to the steel packaging sector. It seeks to demonstrate that opting for more circular and sustainable materials has the potential to generate greater returns for companies, while mitigating environmental risks, and addresses the following questions.

1) What is the material flow in the value chain in the steel packaging sector? 3) What are the barriers and enablers to the adoption of CE principles in the steel packaging sector in Brazil? 3) What opportunities can enable the steel packaging sector in Brazil to become more circular?

The research objectives are to map the life cycle of metal packaging, with a focus on the aggregate flows of material between the main links in the chain, investigate the barriers and enablers to the adoption of circular practices in the steel pack-aging sector in Brazil through interviews, and propose strategies for advancing the circularity agenda in the steel packaging supply chain in Brazil.

2. LITERATURE REVIEW

Given that the concept of a CE is rooted in different schools of thought, its definition has been a major challenge for researchers and scholars in the field (Ghisellini et al., 2016) .

In 1966, economist Benneth Ewart Boulding wrote a seminal article on the principle of conservation, which states that in a simple exchange, one system must give up what another system acquires (Boulding, 1966). This marked the beginning of the CE concept in the academic literature, albeit implicitly (Grafström et al., 2021). Environmental economists Pearce and Turner (1989) later formalized one of the definitions for the EC derived from Boulding's theory and proposed that the traditional linear economy, as described by modern economics, should be replaced by a closed-loop economy in order to be sustainable. They proposed two rules for this new economy: 1) always use renewable resources, so that the rate of use does not exceed the rate of natural regeneration, and 2) keep the flow of waste for disposal in the environment equal to or less than the assimilation capacity of the environment.

Genovese (2017) defines the CE as an idealistic philosophy promoting a regenerative production system in which the circulation of resources and energy is continuously sustained within a closed system, reducing the need for new raw materials and inputs. While perfect circularity may not be achievable, the principles of the CE represent an effective approach to balancing economic growth and environmental protection (Ghisellini et al., 2016).

One of the central concepts of a CE is the "cradle-to-cradle" concept of eco-efficiency (Mcdonough et al., 2003; Kälin et al., 2007), as opposed to the traditional "cradle-to-grave" approach. The CE is aimed at transforming waste into resources and linking production and consumption. Thus, the goal of a CE is to redesign products and processes to maximize resource value and decouple economic growth from the irrational exploitation of natural resources. This can be defined as an economic system that operates in a closed loop of material return (EMF, 2016).

According to Geueke et al., (2018), only certain types of materials can be repeatedly recycled and/or reused (e.g., metals and glass). Steel is one of these infinitely recyclable materials and is the focus of this synthetic literature review.

2.1 Steel packaging industry

One of the key features of steel is that it is 100% recyclable (i.e., it can be recycled repeatedly without a decrease in quality). This versatility allows a steel beam to be transformed into another beam, refrigerator, car door, or packaging. In addition to being continuously recyclable, steel is durable, allowing many products made of steel to be reused (AISI, 2020).

In Brazil, the recycling rate for steel cans is 47.3%, which equates to around 200,000 tons of steel being returned to the manufacturing process. The sustainability of steel cans is further demonstrated in their production process, as recycled steel is a necessary and essential component in the manufacture of new steel (ABEAÇO, 2019).

Recycling steel saves energy reduces the environmental damage caused by mining activities and reduces greenhouse gas emissions into the atmosphere. Steel recycling is beneficial to the CE because it conserves valuable resources and diverts useful materials from landfills. The magnetic properties of steel make it easy to separate from other materials in the waste stream, which allows millions of tons of steel to be recycled every year (AISI, 2020).

However, there are barriers that limit current recycling rates, such as issues with collection and efficiency in material classification (The Canmaker, 2011). If a steel package is not disposed of properly and ends up in the environment (e.g., rivers, oceans, and forests), it will decompose and be reabsorbed in the environment as iron oxide within about 6 years, without causing harm (Hurley et al., 2013).

2.2 Barriers in the transition from the linear economy to the circular economy

Most studies of barriers to a CE have focused on the manufacturing sectors of countries in Europe. In this context, we can highlight the study by Govindan et al., (2018) of Indian manufacturing industries. Identifying and understanding the main obstacles is essential for a successful transition to a CE (Werling et al., 2020).

The regulatory and fiscal environments present barriers to government initiatives to create better economic and financial instruments to promote EC (Govidan et al., 2018). According to the EMF (2021), the only effective way to finance packaging circularity is through schemes that oblige companies to pay for the collection, sorting, and recycling of the packaging they place on the market. The absence of environmental regulations and fiscal incentives to implement circular models are linked to the implications of the underperformance of the CE for management (Mangla et al., 2018)

The transition to a CE is often hindered by the lack of suitable recycling processing technology, which depends on material properties. Technological availability and readiness, infrastructure, the location of processing technology, ease of processing, and significant costs may also affect the transition (Dieckmann et al., 2020). Furthermore, centralized responsibility for pursuing industrial symbioses as a major barrier to supply chains implies that all departments and levels of a supply chain should collaborate to explore and implement opportunities to share resources in the wider chain network. (Hussain et al., 2020) .

Lahane et al., (2020) identified eight main barriers to circularity: a lack of environmental laws and regulations, financial resources, government support, information and knowledge, support for top management, supply chain integration, circular design aspects, and a market for remanufactured products.

Similar barriers, with different names, have been identified in other studies. A literature review revealed 22 barriers, as shown in Table 1.

Table 1
Barriers in the transition from a linear economy to a circular economy based on a literature search.

Item	List of barriers
1	Lack of control at the point of sale (high rate of informality, intermediaries, etc.)
2	Willingness to adopt long-term strategies
3	Collaboration among industry partners, with value chain actors fully committed to implementing reverse logistics
4	Awareness of the importance of reverse logistics in the sourcing of raw materials
5	Selection of reverse channels, with a well-organized network for reverse logistics
Item	List of barriers
6	Lack of channels for acquiring post-use products in the acquisition process
7	A weak return and collection system due to narrow margins (i.e., the amount paid by recycling companies does not cover collection costs)
8	Complexity of the recovery process
9	Volume of raw material recovery and its relationship with liquidity

10	Development of an optimal production configuration for sale to the recycler that meets the specifications required by the recycler
11	Potential for recycled raw material to cannibalize sales of virgin raw material
12	Clean/waste-free production
13	Complexity of products for recyclability
14	Uncertainty regarding the quality of returned and reused products, in line with required quality standards (reuse, recycling, remanufacturing, etc.)
15	Reverse logistics cost (i.e., the cost of bringing material back to the raw material recovery point)
16	End-to-end visibility and supply forecasting capability, including the ability to see the destination of reused products without risk of a lack of liquidity for the sale of collected post-consumer products
17	Interruptions in the collection process, with guarantees that the collection process for reverse logistics will be ongoing
18	Raw material volatility, uncertainty about returns, and doubts about the ability to collect raw material throughout the year (seasonality)
19	IoT integration that is performance-based and focused on long-term results
20	Current legislation for reverse logistics and the responsibilities of actors along the value chain
21	Tax incentives to encourage the revaluation of raw materials
22	Lack of information and knowledge among end consumers

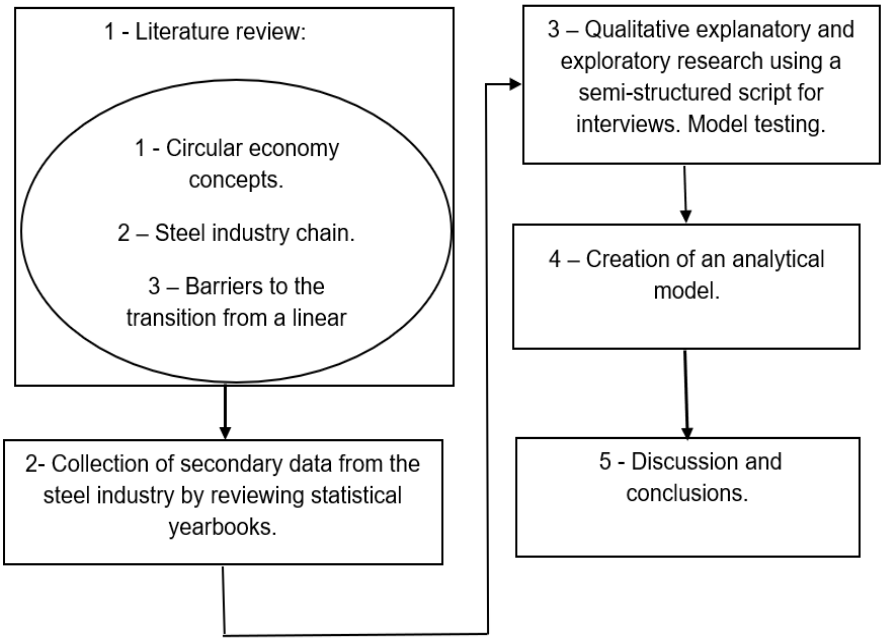
3. METHODOLOGY

This study involved five steps. In the first step, the relevant academic literature was reviewed to understand previously identified constructs. The second step involved analyses of data from statistical yearbooks published by industry associations, the Brazilian Steel Institute (2019), and government agencies, such as the Brazilian Mineral Yearbook/National Mining Agency (2019), related to the steel industry.

In the third step, the research methodology was defined and described. The interview model used a semi-structured script for conducting a qualitative explanatory and exploratory study. The structure of the script was developed based on literature findings and preliminary data from five interviews conducted to test the model.

The fourth step was to create an analytical model that would provide a strong foundation for cross-referencing primary data with secondary data. The final step was to discuss and draw conclusions from the research findings. A schematic representation of the research methodology is shown in Figure 1.

Figure 1
Research approach



The identification of barriers that prevent the transition from a linear business model to the CE, which prompted the qualitative research, was possible by cross-referencing value chain data with data from a literature review on the CE (Dieckmann et al., 2020). This highlighted the need to delve into the field and gain a thorough understanding of the barriers that prevent circularity in the steel packaging sector, identify the enablers that contribute to circularity, and, ultimately, gather the insights needed to propose strategies for moving towards circularity.

This study adopted a qualitative approach, which is useful for obtaining a deep understanding of phenomena that may be difficult to achieve through quantitative investigation (Mcnulty et al., 2013). In-depth interviews are an appropriate way to analyze a phenomenon in a flexible manner (Langley, 2011). The interviews used an abductive approach, as this type of reasoning can be used to infer new elements. Inferences may be accepted as valid or may have provisional validity, depending on the problem at hand (Cochieri, 2008).

The literature review served as the basis for the development of the interview script. Five pilot interviews were conducted to understand how the barriers listed in Table 1 applied to the steel packaging sector. After the model was validated by a panel of experienced researchers, 12 additional interviews were conducted with experts in the sector who had at least 10 years of experience.

3.1 Data collection

To ensure the robustness of the study, a combination of secondary data from the literature and statistical yearbooks for the sector as well as primary, empirical data from interviews was used. This enabled data triangulation (Corley et al., 2011). The cross-referencing of primary and secondary data is an important aspect of explanatory and exploratory research approaches, as the data obtained from interviews may not fully align with the details of the secondary information obtained from the literature (Power, 1985).

Table 1 summarizes the secondary data collected from the literature review. The data from statistical yearbooks published by industry associations, government agencies, and industries indicate that the steel used to make tinplate sheets and chrome sheets with a thickness

of between 0.14 and 0.50 millimeters (used to produce steel packaging) represents 2% of the industry. This niche of the industry is the focus of the research. Primary data were collected through interviews with experts in the steel packaging industry.

3.1.1 Profile of respondents

Table 2 provides profiles for each interviewee, including their expertise, their position, the type of company they work for, and the duration of each interview.

Table 2
Details of the interviews and interviewees

Interviewee	Interview Duration	Position Held	Type of Company
1	31 minutes	Vice president	Steel packaging factory
2	57 minutes	CEO	Prolata
3	33 minutes	Reverse logistics coordinator	Startup
4	37 minutes	Purchasing manager	Paint industry
5	25 minutes	Buyer of Recyclables	Recycling plant
6	44 minutes	CEO	Steel packaging factory
7	50 minutes	Development director	Steel packaging factory
8	45 minutes	Marketing consultant	Supply chain marketing consulting
9	68 minutes	Prosecutor	Public ministry
10	49 minutes	Commercial director	Steel packing factory
11	41 minutes	Sales manager	Steel packing factory
12	42 minutes	Industrial manager	Food factory
13	27 minutes	Packaging development	Paint industry
14	32 minutes	Company's president	Scrap buyer
15	34 minutes	Commercial purchase agent	Scrap buyer
16	58 minutes	Cooperative president	Solid waste sorting cooperative
17	14 minutes	Cooperative president	Solid waste sorting cooperative

3.1.2 Primary data

The interviews were conducted within the constraints imposed by the COVID-19 pandemic. Interactions were recorded using Zoom and lasted an average of 45 minutes. The interviews were guided by a semi-structured interview script based on literature findings. All interviewees signed a consent form, which was kept on file along with the transcripts of the interviews.

3.1.3 Secondary data

The transcripts of the interviews were coded using NVivo software, based on an initial

template that was developed to analyze research questions related to circularity in the supply of steel packaging (Krippendorff, 2004). In addition to primary data from interviews, secondary data were extracted from the literature review (Seale et al., 2004).

The identification of patterns in the secondary data from the literature review and the primary data from the interviews led to the axial coding phase, during which relationships between concepts were identified and constructs were grouped into second-order themes (Gioia et al., 1991). These themes were then structured in a model that aligns with the existing literature, as shown in Figure 2, with the goal of forming the basis for an emerging structure that can be used as a foundation for future studies. The findings were triangulated with the secondary data for validation.

As the analysis of interview data progressed, new data generation was ended. This approach to data generation is in line with emerging theory. Theoretical saturation was reached when data collection did not result in new knowledge or explanations of the topic (Glaser, 1967).

4. RESULTS AND DISCUSSION

To understand the flow of materials, we first narrowed our focus to the value chain of the steel packaging industry to gain a deeper understanding of the value chain of the broader steel industry.

4.1 Steel packaging value chain in Brazil

The steel packaging sector in Brazil is a small part of the broader steel industry, accounting for approximately 2%. The apparent consumption of tinplate in Brazil in 2019 was 413,000 tons, meaning that, including exports and subtracting imports, Brazilian mills had to produce 421,000 tons of steel, of which 206,000 tons came from recycled scrap. As 1 kg of scrap generates 1 kg of steel and 1 kg of ore generates 0.67 kg of steel (IAB, 2020), the packaging sector would need 307,000 tons of ore to generate the remaining 215,000 tons of steel needed to meet demand.

Based on the survey, there is a great opportunity for the steel packaging sector to operate in a closed-loop production system, as 1 kg of post-use material can generate 1 kg of virgin raw material due to the inherent characteristics of steel. This requires the self-organization of the sector to ensure that all packaging is returned to the beginning of the production chain at the end of its life cycle. Based on the triangulation of the findings from the literature with secondary data from statistical yearbooks,

it can be concluded that if all post-use steel packaging is returned to the beginning of the chain, a significant amount of iron ore will no longer need to be extracted by mining to meet the needs of the sector.

4.2 CE barriers and enablers in the steel packaging industry

The purpose of this section is to answer the second research question: *what are the barriers and enablers to the adoption of circular economy principles in the steel packaging sector in Brazil?*

In this study, the term "enablers" refers to the factors that promote or validate the circularity of steel packaging. Our results revealed that many barriers identified in the literature review were enablers of the steel packaging chain, highlighting the great potential of this type of packaging. The expertise of the interviewed experts provided insights that, if implemented, could transform barriers into enablers.

The barriers and enablers to the implementation of CE concepts in the steel packaging sector in Brazil are identified in Table 3. The table presents the classification of the barriers and enablers observed in the literature review that companies face in the transition from a linear model to a circular model. The barriers are marked with an "X" in column B and the enablers are marked with an "X" in column H. These classifications were made by the researchers based on the evidence extracted from the quotes of the interviewees and the coding of the transcripts using NVivo software.

Table 3
Classification of barriers and enablers

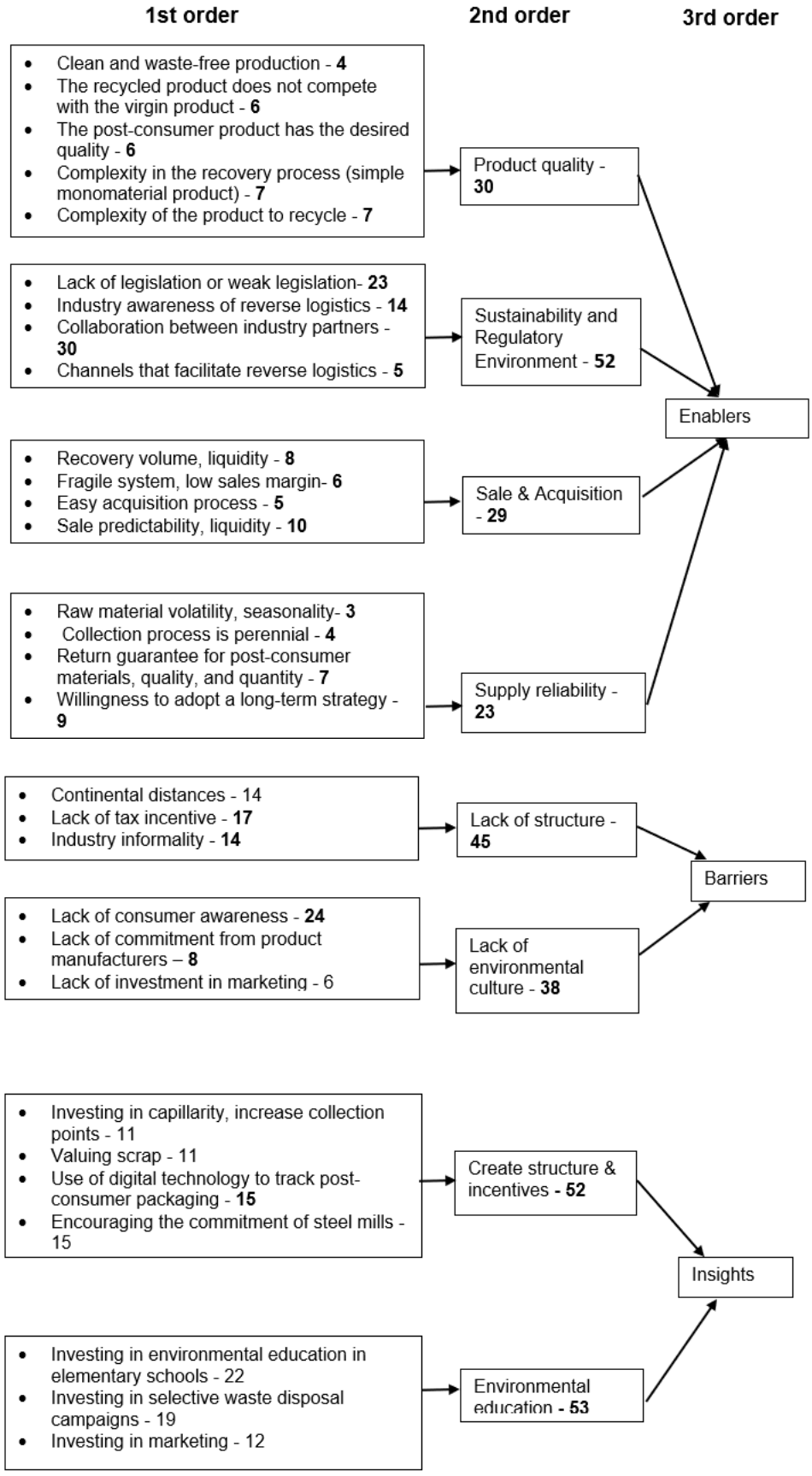
Item	Quotes from respondents	B	E
1	"Formalization and traceability are important because there is a portion of materials that return to the sector but are not disclosed." (3)	X	
2	"Each ton of post-consumer can is turned into a ton of post-consumer material, so extraction is not necessary." (2)		X
3	"I believe that the revaluation of material endlessly is one of the pillars of a sustainable circular economy." (1)		X
4	"I perceive that the steel chain is more structured, although it may not be fully formalized." (3)		X
5	"Scrap has a high turnover and liquidity, so it is easy to handle; it is rare to see scrap discarded on the streets nowadays." (5)		X
6	"Steel is frequently recycled, and pickers see value in it because they can benefit from the recycling and sale of it." (4)		X
7	"Packaging can be reused by being collected, turned into scrap, and returning to the steel mill to be melted in the blast furnace and made into steel again." (1)		X
8	"The great advantage is that the material does not need to be separated or sorted by color, type, or model." (2)		X
9	"Post-consumer steel is a necessary and essential component of the steelmaking process." (2)		X
10	"Technology helps to formalize the sector and improve the traceability of waste by enabling us to know where it comes from and where it goes." (4)		X
11	"We and our main customers, through ABRAFATI, are highly engaged in this." (1)		X
12	"Packaging such as paint cans, food cans, and oil cans are all part of the circular chain and can be turned back into steel." (4)		X
13	"We already have a well-established chain that consumes post-consumer material, which ensures proper disposal." (2)		X
14	"Looking at our daily lives here, the work of the circular economy, with a focus on sustainability, starts from the base." (5)		X

15	"We are aware that this is a challenging task at the national level in Brazil, which is a large and unfortunately still quite poor country. People are also often unwilling to travel long distances to dispose of packaging." (2)	X		
16	"That is why we use Prolata, which has the expertise and development in this area, to try to collect and recycle post-consumer packaging." (3)		X	
17	"The steel manufacturer is a strong supporter, as he uses the recycled steel in the blast furnace to make new steel, which is a significant benefit for him." (4)		X	
18	"Steel is financially interesting as it has considerable value, although it may not be the material with the highest added value." (3)		X	
19	"It is also an easy-to-handle material." (3)		X	
20	"At a minimum, if you are not part of a reverse logistics program, you should still do what such programs do." (2)		X	
21	"Unfortunately, this is not yet the case in Brazil. We know that it is already a reality in some European countries that have a differential in sustainable recycling materials." (1)	X		
22	"I believe there is a lack of information, education, and structured selective collection, and even where such collection exists, the public is still lacking in information." (3)	X		

There was a significant discrepancy between the results of the literature review and interviews with experts. These discrepancies can likely be explained by differences in the raw materials, the organization of the sector, the culture of the population in a developing country, and the structure of the countries where the studies were performed. This study focused on Brazil, while most of the studies in the literature review focused on Europe and North America.

After analyzing the results obtained using NVivo from the empirical data based on the interviews, the number of times each construct was mentioned during the interviews is displayed in Figure 2. The first-order raw constructs, derived from the literature and interviews with experts, were then organized into 2nd-order categories and subsequently into 3rd-order categories, which corresponded to the research sub-questions.

Figure 2
Structuring of data determined using Nvivo



4.3 Strategies to make the steel packaging industry more circular

The objective of this section is to answer the third research question: *what strategies can be used to make the steel packaging sector more circular in Brazil?*

Among various insights, "investing in environmental education in elementary schools" was mentioned by ten respondents. There are indications that this investment will reduce the "lack of consumer awareness," a key barrier, as demonstrated in the following quote: "[...] *In my opinion, this material does not have the same level of recognition and appreciation in Brazil as it does in other parts of the world, particularly in Europe. In Europe, the attributes of steel are highly valued, both for society and for the consumer* [...]." [Interviewee 6].

Other factors that appear to contribute to the attractiveness of post-consumer steel is the action of increasing the price of scrap. According to the experts, this would increase both the collectors' interest in the material and the recycling rate, leading to the proposal of the construct "valuing scrap metal" as a means of making the chain more circular. This action is associated with the barrier of "Lack of fiscal incentives," where it falls upon the legislative body to create clear and objective laws, feasible for enforcement, to promote the use of recycled materials in packaging. If fiscal incentives are provided, this construct could be utilized to encourage the sector to enhance recycling rates. The following quote contextualizes this finding; it identifies the need to find a way to value post-consumer packaging as a means of encouraging packaging return. "*I believe that there needs to be some way of valuing the residue, whether by imposing a tax at the source so that it is carried through to the end and allows for improvements to be made, or by taxing the person who ends up with the residue*". [Interviewee 7].

The interviewees proposed two ideas: (1) to impose a tax on companies that produce products with packaging that is not returned and (2) to charge consumers for special packaging in order to dispose of non-permanent materials.

The last proposal made by the interviewees was to "invest in capillarity, increase collection points," which is related to the barrier of "continental distances." Despite the previously mentioned proposals, Brazil is a very large country with diverse population concentrations and social classes, as noted by the interviewees: "*Fortunately, or not, Brazil is a very large country, much larger than all European countries, which have a more advanced logistical structure and infrastructure than ours*." [Interviewee 1].

The proposals described above were validated by at least five experts, indicating a high likelihood of their relevance. For each barrier, there was a corresponding proposal that, if implemented, could mitigate it.

5. CONCLUSION

This study demonstrated that industry executives and potential customers of steel packaging have at least five reasons to view steel packaging as a viable choice for new product development.

Cause marketing - Steel packaging can be recycled indefinitely (AISI 2020), resulting in significant savings in terms of iron ore, coal, limestone, and energy when recycled. Global recycling rates for steel are high, with rates of 85% for construction, 90% for automobiles, 90% for machinery, and 80% for packaging (Björkman et al., 2014). Additionally, the use of steel packaging in association with a product or brand can convey prestige.

Long-term strategy - Iron ore is abundant in nature, comprising the fourth most common material in the Earth's crust, accounting for 5% (Ferreira et al., 2015). Accordingly, there is no risk of scarcity, and efforts towards reducing, reusing, and recycling iron ore within a circular economy will only increase its abundance.

Environmental risk - The steel packaging sector adheres to existing laws and does not

pose environmental risks. Prolata, a non-profit association, was established by ABEAÇO in 2012 with the goal of complying with solid waste policies, particularly Law No. 12,305/10. It became the first management entity for the reverse logistics of packaging materials with an exclusive federal mandate specific to the sector, as signed in December 2018 with the Ministry of the Environment (ABEAÇO, 2019).

Barriers to the transition from a linear economy to CE - According to the literature review, there are at least 22 barriers to transitioning from a linear economy to CE. However, 18 of these barriers are actually enablers when considering the properties of steel.

Degradability - Steel is biodegradable. If a steel package is improperly discarded and ends up in the natural environment, such as rivers, oceans, or forests, it will decompose and be reintegrated into the environment as iron oxide within about six years, without causing harm to the environment (Hurley et al., 2013).

Contributions to Theory - This study contributed to five areas of theory concurrently. Firstly, it focused on the concepts of circular economy, emphasizing the reverse logistics pillar for materials in a closed loop, enabling the reintegration of materials at the beginning of their life cycle. While the Ellen MacArthur Foundation introduced the concept of closed-loop materials (or infinite materials cycle) in 2016 (EMF, 2016), practical examples demonstrating the application of this concept with raw materials were not explicitly provided until this study. Secondly, it demonstrated that the technical characteristics of steel packaging within the value chain allow post-use material to be reintegrated at the chain's inception, as described in (AISI, 2020). Thirdly, a literature review was conducted to identify the primary barriers in transitioning from a linear to a circular economy. This study contributed to demonstrating that many of the barriers identified by Werning (2019) can be perceived as enablers, contingent upon the study's sectorial and raw material focus. Fourthly, the study validated certain barriers found in the literature, utilizing qualitative research methods that permitted an in-depth exploration. By collecting raw data in the field and analyzing it with a specific focus on steel packaging within the vast Brazilian territory, this methodology provided insights into the challenges faced by a developing country with structural complexities. Fifthly, the study offers contributions to the sector by proposing actions that, if implemented, could further align the sector with circular economy principles. It also elucidates factors influencing the decision-making processes of sector executives. Lastly, the study provides suggestions that could guide future research endeavors in this field.

Methodological limitations - The study, despite its mentioned contributions, presents limitations. One of the main limitations that cannot be overlooked is the bias in the respondents' statements, which may impact the research outcome. Another crucial point is the number of interviews conducted. Despite the careful selection of interviewees, their notable expertise in the discussed subjects, and the interviews only ceasing when their analyses demonstrated theoretical saturation, it cannot be ensured that these interviewed professionals represent the entirety of knowledge within the sector. Given that the objective here is to comprehend the path being taken and forecast the future the sector will pursue, it was necessary to assemble a range of Top Management Team (TMT) members serving as strategists within the sector, including a commercial and an operational group from the market. This led to a restricted group of professionals.

To mitigate bias risks, this study employed a semi-structured script that comprehensively addressed the issues without directly focusing on the research question but rather encompassing the findings from the literature. This approach facilitated fluidity in the interviews, conducted as spontaneous testimonies. Empirical data were cross-referenced with literature, foundations, and professional associations to validate the interview findings. Nevertheless, caution is advised in analyzing the transferability of the findings from this study to other scenarios and materials.

Final remarks - Finally, we can say that this study will bring knowledge and contribute to the decision-making process of industry professionals who seek information about the steel packaging sector, particularly with regard to the circularity of the steel packaging supply chain, and marketing professionals in companies that are seeking more sustainable materials for packaging products in an environmentally responsible and sustainable manner.

Another practical contribution of this study is that it can serve as a guide for the implementation of sustainability policies in companies within the sector, and, in some cases, in packaging companies from other sectors that are transitioning from a linear to a circular economy.

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