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Evaluation of the Circular Economy in the Supply Chain of Mining Industries

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Abstract

In supply chains, the circular economy is a good practice that influences the change of: processes and flows, relations between actors from different sectors, financial management, the role of suppliers and the form of consume of the consume of the customers. For these reasons, the circular economy becomes a challenge for supply chains in the path of reaching circularity. This research aims to evaluate the circular economy in the supply chain of mining industries in the province of Manabí, Ecuador, through diagnostic techniques. An investigation was conducted at the province of Manabí, Ecuador. The mining industries and other companies related to this activity were identified. With this information, the map of the study chain was prepared. A checklist was applied for the evaluation of the circular economy. This tool has nine variables (source or supply of materials (raw materials), design, manufacturing, economic circle, distribution and sales, consumption and use, collection, relocation and sustainability) and 91 items. A Likert scale of: 1 (very low), 2 (bass), 3 (medium), 4 (high) and 5 (very high) was used. At the same time, eleven principles and five characteristics of the circular economy in the chain are valued. As a result, it was obtained that the circular economy level of the chain is medium, with a value of 3.08. The variables with greater weak, distribution and sales (with an average of 2.97) and consumption and use (with an average of 2.98). The principles of low evaluation is: industrial and territorial ecology, and the use of materials (value 1 is very low). The affected characteristics is to work towards energy use from renewable sources (with a value of 2, low). In addition, the environmental impacts of this chain were analyzed. This element is a starting point to continue research.

Keywords
Supply chain, circular economy, mining industry and circularity.

1. Introduction

The supply chain (SC) is a set of suppliers, factories, warehouses, distribution centers and retail sales; through which raw materials are acquired and transformed, to deliver products or services to the customer (Bautista Santos et al., 2015). At the same time, these actors and links must be integrated (Sablón-Cossío, Crespo, Pulido-Rojano, Acevedo-Urquiaga, & Ruiz Cedeño, 2021). The objective of the SC is the satisfaction of the clients and the optimization of the

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costs. Along this path, the SC seeks practices that foster improvement. Circularity is located within these practices (Farooque, Zhang, Thürer, Qu, & Huisingh, 2019).

Circularity in CS processes and flows is a necessity on the way to optimizing resources in the chain and product innovation (González-Sánchez, Settembre-Blundo, Ferrari, & García-Muiña, 2020). Some authors define CS as a series of processes that contribute to improving the useful life of products and allow the core restoration and regeneration processes to be implemented by business model innovations that aspire to Circular Economy ideas (Batista, Bourlakis, Smart, & Maull, 2019). Where the process of collaboration with clients requires a change in the culture of consumption and in the process of suppliers, such as balancing productions in scale (Taddei, Sassanelli, Rosa, & Terzi, 2022). This has a lesser influence on the finances of these actors.

For this reason, a group of barriers that hinder the implementation of circularity in CS are studied. For example, the analysis by Roy, Garza-Reyes, Kumar, Kumar, and Agrawal (2022), where certain barriers are grouped into groups: organizational, competitive, and technological; supply chain integration; customer behavior and reverse supply chain barriers; products and processes; regulatory and standardization; and the economic and financial ones. These elements have been the basis for new studies and approaches to circularity in CS.

The objective of this scientific work is to evaluate the circular economy in the supply chain of mining industries in the province of Manabí, as a first approximation on issues of circularity in this sector in Manabí - Ecuador. As background to this work is the research of Reyes and Zambrano (2022), where the primary information was obtained.

2. Methodologies and method

This research is field. Where a checklist was applied for the evaluation of the circular economy (Diéguez-Santana, Rodríguez Rudi, Acevedo Urquiaga, Muñoz, & Sablón-Cossio, 2021). This tool has nine variables: (source or supply of materials (raw materials), design, manufacturing, economic circle, distribution and sales, consumption and use, collection, relocation and sustainability) and 91 items. A Likert scale of: 1 (very low), 2 (bass), 3 (medium), 4 (high) and 5 (very high) was used.

The scale variables that determine the level of CE of the supply chain and company were calculated using Equations 1 and 2 (Diéguez-Santana et al., 2021). In the case of Equation 1, the 91 items on a Likert scale were consulted for determination.

$$CEL = \frac{\sum_{j=1\ \forall j \in m}^{n} \mathrm{CEL}_j}{n} \qquad (1)$$

Where:
CEL: scale variable that determines the level of circular economy of a supply chain m, seen as the average of the CEL of all the companies j that compose it.
m: nominal variable that identifies the supply chain.
j: nominal variable that identifies the company's belonging to supply chain m.
Ekj: ordinal variable measured on a Likert scale from 1 to 5 (Very low = 1, Low = 2, Medium = 3, High = 4 and Very high = 5), where k corresponds to the 91 items in the checklist. k = {1, 2.... 91}, grouped by each dimension.
Dij: scale variable calculated from the mean of the corresponding Ek.
Equation 2 determines the level of circular economy calculated for the company or sector (NECj) based on the results of the dimensions and variables previously obtained.

$$\mathrm{CEL}_j = \sum_{i=1}^{9} (w_i * D_{ij}) \qquad (2)$$

CEL j: scale variable that determines the circular economy-level calculated for company j.
wi: specific weight determined for each dimension Di.

The CEL evaluation criteria obtained from the scale variables were categorized according to the scores obtained for each of them. The interpretation intervals for the CEL variable in this case were: very low (1.5), low (> 1.5 and 2.5), medium (> 2.5 and 3.5), high (> 3.5 and 4.5), and very high (> 4.5). This numerical value allows the state of the object

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of study to be compared with other national and international benchmarks to promote its development (Diéguez-Santana et al., 2022).
The principles, characteristics and elements of the circular economy are valued (MacArthur, 2013) from 1 to 5; 1 being the lowest score and 5 the highest.

3. Results

In the object of study, the materials that are present are shown in Table 1.

Table 1. Description of the material extracted from the Manabí quarries.

Material de extraccion		Reference
Aggregates	Sand, Clays, Gravel, Gravel, Diorite, Gabbros, Basalts, Sandstones, Greywacke, Porphyries, Conglomerates	António Paz (2019)
Stony	River stone, Marble, Rubble, Slate, Gravel, Granite, Ball stone	Herrera Moran (2018)
Feldespato		

The mapping of the chain under study was carried out. The links and actors were recorded: suppliers (3), producers of materials (18), manufacturers (2), vendors (distributed in 3 zones). Circular economy tools were applied to these stakeholders. The result of the checklist is shown in Figure 1.

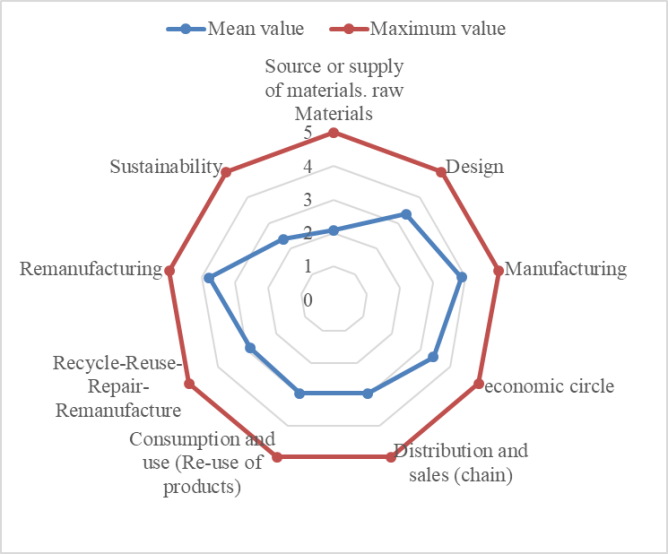

Figure 1. Result of the variables of the circular economy checklist.

The variables with the greatest weakness are identified as: source or supply of materials, raw materials (with a mean of 2.08), followed by sustainability (with a mean of 2.37), remanufacturing (with a mean of 2.88), distribution and sales (with a mean of 2.97), consumption and use (with a mean of 2.98), design (with a mean of 3.35), economic circle (with a mean of 3.43), Re-manufacturing (with a mean of 3.79), manufacturing (with a mean of 3.87). From these results, the level of circular economy of the chain was calculated. This was estimated with a value of 3.05 (mean level).

The principles of the circular economy are evaluated (Figure 2):

- ✓ Preserving and enhancing natural capital is evaluated at 3 because there is recovery of renewable resources since material is extracted from the natural soil
- ✓ Optimize the use of resources) is estimated with a value of 4 because there is a good use of materials,
- ✓ Promoting the effectiveness of the system is estimated at 3 because there are external factors that allow the effectiveness of the system, although there are also artisanal quarries that do not have patents, so it is given an average value,

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- ✓ The eco conception is estimated at 4 because the product is from its extraction, its environmental impact is taken into account,
- ✓ The industrial and territorial ecology is evaluated with a value of 1 because within the organization of the associations not all the actors that extract the material are involved,
- ✓ The economy of functionality is evaluated with a value of 3 because the waste generated is used to generate more products,
- ✓ The second use is given a value of 1 since the products that have been used for customers is a material that is used only for one purpose.
- ✓ Reuse) is given a value of 5 because they use certain residues for the production of new products such as gravel,
- ✓ The repair is given the value of 3 because the extracted material is used in its entirety,
- ✓ Recycling is given a value of 4 because the extracted material is put into bags and generates waste.
- ✓ The valorization is given the value of 4 because in the extraction of materials the material residues are used to the maximum.

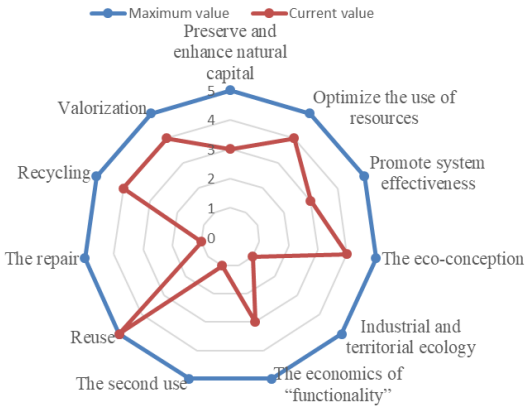

Figure 2. Principles of the circular economy

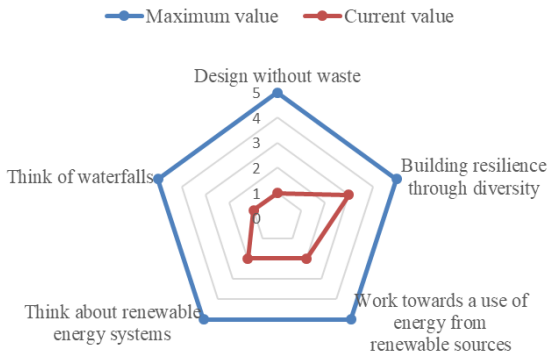

Figure 3. Characteristics of the circular economy

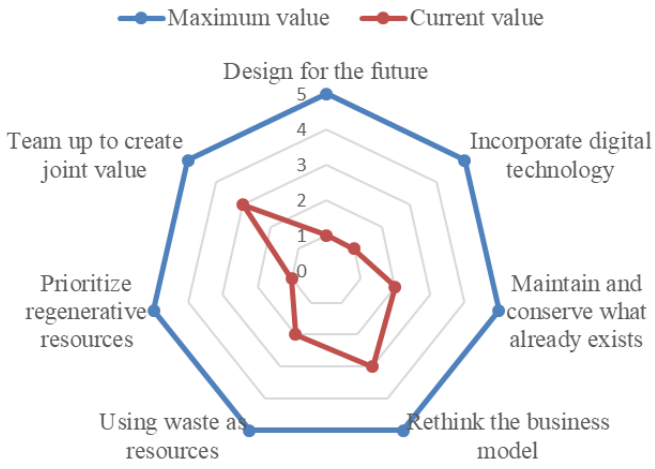

Figure 4. Key elements for the circular economy

The results of the characteristics of the circular economy are shown in Figure 3:

- ✓ Designing without waste was evaluated with a value of 5, because the material extracted and put up for sale is done under the condition of not generating waste.
- ✓ Increasing resilience through diversity is estimated with a value of 4, because the extraction process improves over time in both production and environmental impact.

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- ✓ Working towards the use of energy from renewable sources is evaluated with a value of 2, because the production of the product is not subject to the use of renewable energies since fuel is used for its processes.
- ✓ Thinking about renewable energy systems was evaluated with a value of 4, because the extraction process does not use renewable energies, but the actors do see that it can be applied in the future and
- ✓ Thinking in cascades was estimated at a value of 3, because the elaboration of the final product generates an additional commercial value to the cost of production.

The results of the elements of the circular economy are shown in Figure 4:

- ✓ Design for the future was estimated with a value of 1, because the material extracted and commercialized systematically does not allow changing its way of production,
- ✓ Incorporating digital technology was evaluated with a value of 5, since various machinery and technologies are integrated into its production process.
- ✓ Maintain and conserve what exists was estimated with a value of 2, since the product does not have the possibility of a single use.
- ✓ Reconsider the business model, a value of 4 was evaluated, because it has a non-circular business model despite the fact that they are willing to create better opportunities,
- ✓ Using waste as a resource was evaluated with a value of 4, because the waste is reused to obtain a new highly commercialized product.
- ✓ Prioritizing regenerative resources was estimated with a value of 2, since efficient renewable energy is not used in production,
- ✓ Building a team to create joint value was rated 2 because producers work directly with their customers and suppliers.

In this type of chains in Ecuador, there are a group of regulations:

- Ordinance to regulate, authorize and control the exploitation of dry and stone materials found in existing quarries in Manabí
- The Mining Law regulates the exercise of the sovereign rights of the Ecuadorian State, to administer, regulate, control and manage the strategic mining sector, in accordance with the principles of sustainability, precaution, prevention and efficiency;
- Organic Law of the inclusive circular economy
- Environmental regulation of mining activities of the Ministry of Environment, Water and Ecological Transition.

Despite these regulations, mining exploitation areas present high environmental contamination. This result correlates with the weakness of the sustainability variable.

When comparing semilar studies of the circular economy with other sectors, a higher level of circular economy is evidenced, although in the authors' opinion, this is due to the environmental plans that the exploitation areas must comply with (Table 2). At the same time, the circular approach of materials from earth to earth was not evident.

Table 2. Comparison of the results of this study with other cases of evaluation of CE in supply chains

No	Criterion	Cacao chain, Mexico	Organic Cacao, Manabí-Ecuador	Coconut Chain, Manabí - Ecuador	Banana Chain, Manabí -Ecuador	Pitahaya, Tena-Ecuador	Mining industries, Ecuador
	Reference	(Diéguez-Santana et al., 2021)	(Bravo, Ruis Cedeño, & Sablón Cossío, 2020)	(Diéguez-Santana et al., 2021)	(Silva Alvarado, Sablón Cossío, & Bravo Giler, 2021)	(Diéguez-Santana et al., 2022)	This work
1	Source or supply	2.54	2.06	1.09	2.63	1.72	2.08
2	Design	2.25	2.69	1.40	2.88	1.93	3.35
3	Manufacturing	2.80	1.30	1.81	2.83	2.60	3.87
4	Business cycle	3.50	2.00	2.39	2.68	2.45	3.43
5	Distribution and sales	3.23	2.98	1.39	2.72	1.75	2.97

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6	Consumption and use	3.22	1.19	1.46	2.66	2.20	2.98
7	4R	2.94	1.64	1.30	2.69	2.10	2.88
8	Re-manufacturing	2.80	1.00	1.01	2.93	1.75	3.79
9	Sustainability	3.50	4.03	2.21	2.94	2.75	2.37
-	CEL	2.98	2.10	1.56	2.77	2.14	3.05

4. Conclusions

This work is a preliminary study that allowed the evaluation of the circular economy in the supply chain of quarries in Manabí -Ecuador, through a checklist. At the same time, the principles, characteristics and elements of the circular economy were analyzed. The theoretical elements of the circular economy and its application in the supply chain of quarries in Manabi-Ecuador were founded. The types of existing quarries and the materials they supply were defined, throwing the different varieties of mining and classifying them according to the type of material they exploit. This will allow future research to continue the study of circularity in the chain with studies of subjects.

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