Identification of the barriers to the adoption of Circular Supply Chains in Moroccan companies: A combined qualitative analysis and Multi-Criteria Decision Model approach

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Abstract. The Circular Economy has been gaining a growing interest in the research community, particularly in recent years. Its application to the Supply Chain Management field is gaining traction in the literature, as the Supply Chain is recognized as a primary avenue for implementing circular models. However, despite this growing interest, there are few documented examples of the implementation of circular supply chains. This article presents a prioritization of barriers to the adoption of circular supply chains using a combined qualitative analysis and Multi-Criteria Decision Models (MCDM) approach. The study identifies 28 barriers grouped into six main categories: financial barriers, regulation barriers, expertise and technology barriers, governance barriers, market barriers, and infrastructure barriers. The prioritization is based on a multi-case study involving six Moroccan companies. The findings highlight the predominance of regulation barriers, followed by financial barriers. Additionally, the study shows the significant role of market barriers in impeding progress toward circularity.

1 Introduction

In recent years, the Circular Economy has garnered an increasing interest within the research community, particularly in the context of resource scarcity and a growing demography. Although the concept was initiated 60 years ago by Boulding (Lieder et al., 2016), its definition has known divergent views and has evolved to reach a relative consensus over the past five years (Farooque et al., 2019; Bressanelli et al., 2018; Kalmykova et al., 2017; Masi et al., 2017).

The Circular Economy is seen as an alternative to the traditional linear model "Take-Make-Use-Dispose". Although there is no certainty about its origins, the idea is commonly attributed to Boulding in his article published in 1966 "The Economics of the Coming Spaceship Earth" (Aasma & Grafstrom, 2021).

Furthermore, Ellen MacArthur Foundation has played a major role in democratizing the concept of the circular economy. Founded in 2009, it defines the circular economy as a model "designed to eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature. It's an economic system that delivers better outcomes for people, and the environment.". Another example of the definition of circular economy is Stahel's, who defines it as "an industrial system based on restorative and regenerative design thinking, far more sustainable than the dominant linear economic model" (Stahel, 2016).

Therefore, the agreed definition found in the literature could be summarized as follows: the circular economy is a regenerative and restorative model by design and by intention that

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allows moving from a traditional linear model to a circular one, to minimize the use of natural resources and energy (Geissdoerfer et al., 2016; Bocken et al., 2017; Tura et al., 2018).
The Supply Chain is described as the primary vehicle for implementing a circular model (Geissdoerfer et al., 2018). Supply Chain Management is the integrated and coordinated management of the physical, financial, and information flows across the value chain that aims at fulfilling customer demand while enhancing efficiency (Stadtler et al., 2014; Mentzer et al., 2001; Stock & Boyer, 2009). As a result, a new concept known as "Circular Supply Chain" has emerged in the literature, defined as the application of circular thinking to Supply Chain Management (Farooque et al. 2019; Batista et al., 2018). As part of Circular Supply Chains, several types of circular cycles are described among the research community. The most exhaustive framework is the 10R model that includes: Reduce, Reuse, Recycle, Repair, Remanufacture, Refurbish, Recover, Refuse, Renew, Repurpose (Batista et al., 2018; Bressanelli et al., 2018; Geissdoerfer et al., 2018; González-Sánchez et al., 2020; Lahane & Kant, 2021; Kazancoglu et al., 2020).
Since this new concept is still in its infancy, several authors have started to analyze the barriers to the implementation of circular Supply Chains. This article aims to prioritize these barriers based on a combination of multi-criteria decision models with a qualitative analysis through a multi-case study of Moroccan companies.
Therefore, the research questions addressed in this article in the context of Moroccan companies are the following:

1) What are the cause-effect relationships existing between these barriers?
2) What are the predominant barriers?

The first section will be dedicated to the methodology. The second section will describe the results of the literature review, and the third section will describe the results of the empirical study. Finally, the conclusion will highlight future research perspectives.

2 Methodology

First, a literature review has allowed identifying the barriers to the adoption of circular supply chains as cited in the literature (Assemlali et Sabar, 2023). The second step consists of reviewing the multi-criteria decision models to select the relevant ones to prioritize the barriers. The last step implies prioritizing these barriers through a multi-case study of six Moroccan companies. The methodology is described in the following figure.

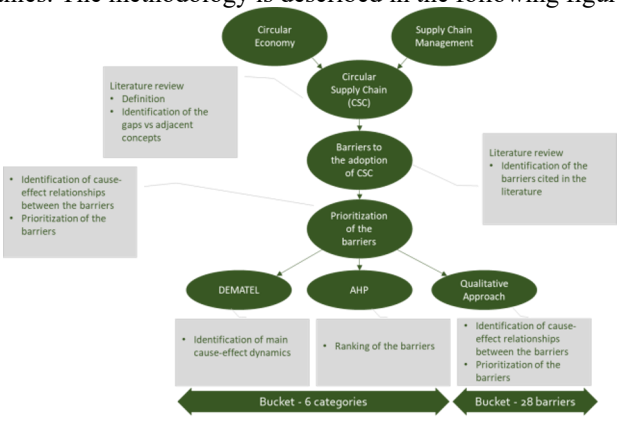

Fig. 1. Summary of the methodology

3 Literature Review

3.1 Barriers' framework

A framework of 28 barriers was developed through a systematic literature review (Assemlali et Sabar, 2023). These barriers are summarized in six main categories which were frequently cited in several publications (Tura et al., 2018; Govindan et al., 2018; Mangla et al., 2018; Kazancoglu et al., 2020): financial barriers, regulation barriers, expertise and technology barriers, governance barriers, market barriers, infrastructure barriers.

Table 1. Summary of the barriers to the adoption of circular models based on the literature review (Assemlali et Sabar, 2023)

1	**Financial barriers**
1.1	Lack of financial resources (Farooque et al, 2019; Khandelwal & Barua, 2020; Vermunt et al., 2019)
1.2	Major upfront investment costs (Govindan et al., 2018; Kazancoglu et al., 2020; Khandelwal & Barua, 2020; Kumar et al.,2021; Vermunt et al., 2019; Aasmaa & Grafstrom, 2021; Ozkan-Ozen et al., 2020)
1.3	Lack of economic benefits in the short-run (Mangla et al., 2018; Govindan et al., 2018; Khandelwal & Barua., 2020; Kumar et al.,2020; Ritzen & Sandstrom, 2017)
1.4	Uncertainty about benefits (Farooque et al, 2019; Kazancoglu et al., 2020; Vermunt et al., 2019; Aasmaa & Grafstrom, 2021; Ozkan-Ozen et al., 2020)
1.5	Lack of economies of scale (Farooque et al, 2019; Kazancoglu et al., 2020)
1.6	High costs of recycled or environmentally friendly materials (Govindan et al., 2018; Kazancoglu et al., 2020; Khandelwal & Barua, 2020; Vermunt et al., 2019; Grafstrom et al., 2021)
1.7	Higher production / logistics costs (Govindan et al., 2018; Vermunt et al., 2019)
2	**Regulation barriers**
2.1	Weak environmental regulation (Farooque et al, 2019; Mangla et al., 2018; Govindan et al., 2018; Khandelwal & Barua, 2020; Kumar et al.,2020; Vermunt et al., 2019; Ozkan-Ozen et al., 2020)
2.2	Lack of preferential tax policies / incentives for promoting circular models (Mangla et al., 2018; Govindan et al., 2018; Khandelwal & Barua, 2020; Vermunt et al., 2019; Aasmaa & Grafstrom, 2021)
2.3	Lack of certifications / standards related to circular economy (Mangla et al., 2018; Govindan et al., 2018; Kazancoglu et al., 2020; Vermunt et al., 2019)
2.4	Lack of governmental support (Kumar et al.,2020)
3	**Expertise and Technology barriers**
3.1	Limited expertise, technology and information / Lack of skilled workforce (Farooque et al, 2019; Mangla et al., 2018; Govindan et al., 2018; Kazancoglu et al., 2020; Khandelwal & Barua, 2020; Kumar et al.,2020; Vermunt et al., 2019; Ozkan-Ozen et al., 2020)
3.2	Difficulty for companies to manage product quality through the lifecycle (Govindan et al., 2018; Kazancoglu et al., 2020; Khandelwal & Barua, 2020)
3.3	Design challenges to reuse and recovery products (Govindan et al., 2018; Kazancoglu et al., 2020; Vermunt et al., 2019; Ritzen & Sandstrom, 2017)
3.4	Challenges to safe return to the biosphere (Govindan et al., 2018)
4	**Governance barriers**
4.1	Unclear vision on how to apply Circular Economy in the Supply Chain field (Mangla et al., 2018; Govindan et al., 2018; Khandelwal & Barua, 2020)
4.2	Higher priority of other issues related to Supply Chain Management (Govindan et al., 2018)

4.3	Resistance to change (from top management to middle / lower collaborators) (Farooque et al, 2019; Mangla et al., 2018; Kazancoglu et al., 2020; Khandelwal & Barua, 2020; Kumar et al.,2020; Vermunt et al., 2019; Grafstrom et al., 2021)
4.4	Lack of a standard system for performance indicators (Govindan et al., 2018; Kazancoglu et al., 2020; Khandelwal & Barua, 2020; Kumar et al.,2020)
4.5	Difficulty to measure the benefits of implementing a Circular Supply Chain (Ritzen & Sandstrom, 2017)
4.6	Lack of collaboration between supply chain actors and ecosystem (Farooque et al, 2019; Mangla et al., 2018; Kazancoglu et al., 2020; Khandelwal & Barua, 2020; Vermunt et al., 2019)
5	**Market barriers**
5.1	Lack of market preference / pressure from both customers and consumers (Farooque et al, 2019)
5.2	Difficulties in establishing correct price of products (Govindan et al., 2018)
5.3	Bad consumer perception towards reused products or components / Insufficient market demand (Mangla et al., 2018; Govindan et al., 2018; Khandelwal & Barua, 2020; Kumar et al.,2020)
5.4	Lack of public awareness (Mangla et al., 2018; Govindan et al., 2018; Kazancoglu et al., 2020; Khandelwal & Barua, 2020; Vermunt et al., 2019; Aasmaa & Grafstrom, 2021)
6	**Infrastructure barriers**
6.1	Insufficiency of reverse logistics infrastructure / Insufficient collection centers (Kazancoglu et al., 2020; Khandelwal & Barua, 2020; Kumar et al.,2020)
6.2	Inadequate facility infrastructure (Kazancoglu et al., 2020; Kumar et al.,2020)
6.3	Complexity of collection and separation processes (Govindan et al., 2018; Kazancoglu et al., 2020; Vermunt et al., 2019)

3.2 Multi-criteria decision models

The focus in this section will be on the selection of Multi-Criteria Decision Models to prioritize these barriers.
One definition of Multi Criteria Decision Analysis (MCDA) is the following:
"Multi-criteria decision analysis (MCDA) methods have been developed to support the decision maker in their unique and personal decision process. MCDA methods provide stepping-stones and techniques for finding a compromise solution." (Multi-Criteria Decision Analysis, Ishizaka & Nemery - Wiley Edition). Multi-criteria decision models are at the intersection of several disciplines such as mathematics and economy (Behzadian et al., 2012).

Two models were selected among the available models cited in the literature: DEMATEL (Decision-Making Trial and Evaluation Laboratory) and AHP (Analytical Hierarchy Process). The selection of DEMATEL is determined by the necessity to identify the cause-effect relationships among the barriers to the adoption of circular supply chains. The primary objective of DEMATEL method is to specifically manage cause-effect relationships and dependencies between alternatives (Farooque et al., 2019), which is one of the key research questions addressed in this publication. Furthermore, several authors have established the existence of dependencies among the barriers to the adoption of circular supply chains (Aasma & Grasfstrom, 2021; Kirchherr et al., 2018). Moreover, this method is relevant and adapted to complex environments, which is the case in this publication with 28 barriers selected in the literature (Si et al., 2018).
Regarding the AHP method, it enables the prioritization and ranking of the barriers for problems with independent criteria. In the context of this publication, the alternatives are

dependent, whereas the criteria are independent. It is described as less complex than other methods due to the use of peer comparisons instead of absolute evaluation (Lindfors, 2021). Lastly, the addition of other models to the DEMATEL application is described as a way to improve its results (Gölcük & Baykasoʟlu, 2016).

4 Case Study Results

This publication relies on a multi-case study involving six Moroccan companies. Semi-structured interviews were conducted and different types of data were collected. For each level (6 categories of barriers and 28 detailed barriers), the following data is collected:

- Identification by each respondent of the most important barriers
- Identification by each respondent of the existing cause-effect relationships between the barriers
- Comparison by peers of each category of barriers to the others and evaluation of the priority using Saaty scale (only for the 6 categories of barriers).

The comparison by peers is done to apply DEMATEL and AHP, which require quantitative data. It is only conducted at the category level due to the complexity of performing it at a detailed level, given the high number of combinations (28x28).

4.1 Application of DEMATEL & AHP

The following figure is the representation of the results of the analysis of the data collected through semi-structured interviews conducted with 6 cases of Moroccan companies.

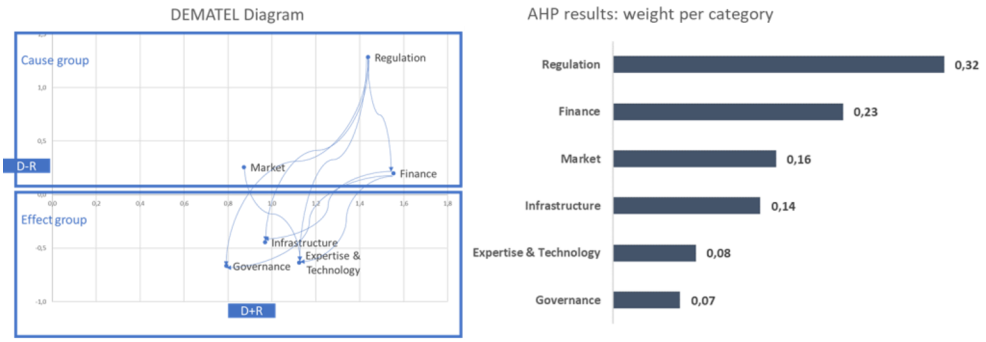

Fig. 2. DEMATEL Diagram & AHP Weights per category Results

For DEMATEL, D-R represents the net causal value: a positive value of D-R implies that the barrier belongs the cause group and a negative value to the effect group. As to D+R, it represents the importance value: a high value of D+R implies that the barrier has important relationships with other barriers.

Three main conclusions can be drawn from the DEMATEL diagram. First, the financial barriers, the barriers related to regulation, and those related to the market belong to the cause group. Second, the financial barriers are those with the most intense relations to the other barriers. Third, the barriers related to regulation are those with the highest net causal value and this value is significantly higher than the other categories of barriers.

Regarding AHP, its application reveals that the ranking of the categories of barriers is the following: regulation-related barriers, financial barriers, and market-related barriers.

Furthermore, the results indicate that the barriers related to infrastructure carry almost the same weight as those related to the market.

4.2 Application of a qualitative approach

The qualitative approach is conducted using Nvivo software. This allows analyzing the barriers at the detailed level, but also at the macro level.

Ranking of the barriers

Categories of barriers Level (6)

Regulation and financial barriers are those that are the most cited by the respondents.

Detailed barriers Level (28)

The ranking is the following: lack of economic gain in the short term (financial barrier), insufficient preference and pressure by consumers and clients (market-related barrier)

Cause & Effect Relationships

Categories of barriers Level (6) – Cause-Effect relationships

Three predominant relationships are identified: Expertise & Technology → Finance; Regulation → Expertise & Technology; Regulation → Infrastructure

Detailed barriers Level (28) – Cause-Effect relationships

Three predominant relationships are identified: Lack of scale economy → Lack of economic gain in the short term; Lack of governmental support → Lack of tax policies and incentives; Lack of governmental support → Weak regulation related to the environment

4.3 Aggregation of the results

Based on the results described in the previous sections, three main conclusions can be drawn.

1) Across the two approaches applied, barriers related to regulation emerge as the predominant category. This is further corroborated at the detailed level, as the lack of governmental support barrier is identified as a "cause" barrier to the lack of tax policies and incentives, as well as weak regulation.
2) Although the financial barriers are not ranked in the first position, they are systematically cited as important barriers to be tackled.
3) Several elements in the results indicate that the market barriers are also significant barriers that impede the adoption of circular supply chains.

5 Conclusion

This research work allowed defining a framework of 28 barriers to the adoption of circular supply chains, grouped into six main categories. The prioritization of these barriers is conducted using a combined approach of multi-criteria decision models and a qualitative approach relying on a multi-case study of six Moroccan companies.

To the best of our knowledge, no article has employed a combination of DEMATEL and AHP to prioritize the barriers to the adoption of circular models, which represents the original contribution of this publication.

The prioritization reveals that in the context of Moroccan companies, regulation, followed by financial barriers are the most significant barriers impeding the adoption of circular supply chains. These results are aligned with those of Farooque et al. (2019) who identify regulation as the most important barrier in the context of China and the food industry. However, the

results shared in this publication differ from those of Farooque et al. on the higher importance of market-related barriers in the Chinese context.
As a conclusion, this publication aims to assist companies in identifying strategic levers to accelerate the transition to circular supply chains. Future research could delve deeper into specific industries or focus on enablers rather than barriers.

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