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# Barriers to Transitioning Towards Smart Circular Economy: A Systematic Literature Review

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**Abstract.** This paper defines smart circular economy as an industrial system that uses digital technologies to implement circular strategies such as reduce, reuse, remanufacturing and recycling. The smart circular economy has been regarded as a promising approach to enhance sustainability. However, barriers exist in various stages of the transition towards smart circular economy. This paper employs a systematic literature review to identify the main barriers that prevent companies from this transition. We adopt a change management perspective to study this transition and propose that it follows a classical three-step process of organizational change: unfreeze, move, and refreeze. We identified 24 barriers in five categories: finance, management, infrastructure, network, and technology. Then, we placed the barriers into the three steps to further investigate how they affect each stage of the transition. Our analysis suggests that: (a) stakeholders play a central role in the process; (b) companies often have financial issues in the early steps of change; (c) technological challenges emerge in the advanced steps. The findings can help diagnose companies' current status, identify solutions to tackle the barriers and predict future challenges.

**Keywords:** Smart Circular Economy, Sustainability, Digitalization, Change Management, Barriers.

## 1 Introduction

Circular economy (CE) is an industrial system that reduces and reuses productive resources taking into account environmental, economic, and social impacts [1,2]. It stands out as a sustainable alternative to manufacturers that extract raw materials from nature and discard the waste [3]. The concept can be translated into circular strategies like the 9Rs proposed by Potting et al [4]. These strategies can be enabled and potentialized by digital technologies (DTs) such as internet of things and big data [5].

We define smart circular economy (SCE) as *an industrial system that uses DTs to provide intelligent functions for implementing value-added circular strategies*. For example, data collection and analysis can be automated by the internet of things and advanced alghoritms. This intelligent function enable failure prediction and preventive maintenance, which are strategies to improve resource efficiency [6-8]. In short, it is a system that uses DTs to foster circularity.

Recently, research has focused on the early stages of CE transition, such as identifying opportunities and designing business models (BMs) [9]. Topics related to implementing organizational change, such as business strategy and management models, are rarely discussed [10]. However, to succeed in the transition, organizational aspects are as relevant as conceptual and technological development. To address this problem, this paper takes a comprehensive view of organizational transformation provided by change management theory. It has been widely adopted to analyse CE transition [11], and we extend this importance to the SCE.

Incorporating DTs generates new barriers to the transition towards a circular system. It conflicts with other business factors, like costs, and results in new business challenges, such as data management [12]. This topic has received wide academic interest, but there is still little consensus. Most of the results from articles cannot be generalized since they analyze specific sectors and countries. The comparison is difficult because the nomenclature of barriers is not standardized, and the papers differ in research methodology.

Therefore, this paper provides a review of the previous studies to built comprehensive knowledge about barriers to the SCE. This work aims to analyze publications on the topic to answer the research question: ***What are the main barriers at each stage of the transition towards SCE?***

The remainder of this paper is structured as follows. Section 2 describes the research methods. Then, Section 3 presents the results and discussion. Some final remarks are summarized in Section 4.

## 2 Research Methods

We conducted a systematic literature review (SLR) [13]. This methodology results in a theoretical model based on the information accumulated by previous studies. It is an explicit and rigorous process. It prevents the author's bias from hampering understanding the topic and allows practitioners and other researchers to use the results. Each stage is described below to ensure the transparency and reproducibility of this research.

### 2.1 Selection of Publications

The first stage focused on identifying relevant publications. The selection was conducted between November and December 2020. Scopus and Web of Science databases were chosen due to their coverage of academic articles. Only journal and conference papers were included to ensure reliability and to reduce publication bias

[14]. Exclusion criteria related to language and year of publication were unnecessary, as all articles were in English and have been published in recent years.

**Fig. 1** shows an overview of the process, including the number of the remaining papers at each SLR stage. Titles and abstracts were examined to identify relevant works based on two inclusion criteria. Finally, we read the full text of the selected publications and excluded those without any specific barriers to the SCE.

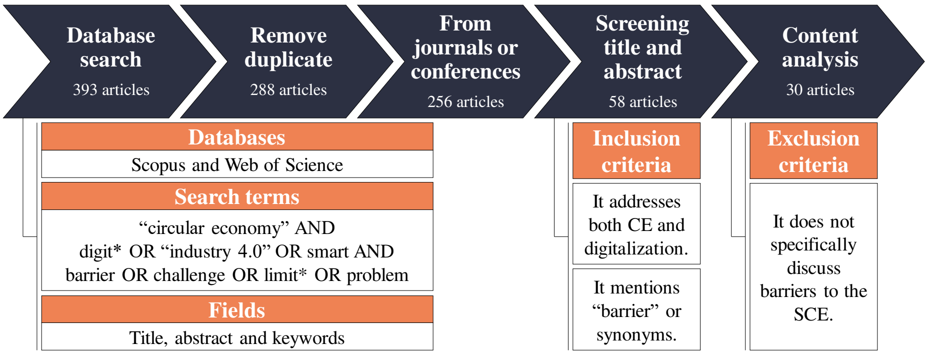


**Fig. 1.** Methodological procedure.

### 2.2 Content Analysis

The second stage focused on extracting and analysing data from the articles. We used MAXQDA software to support the process and conduct the qualitative data analysis [15]. We coded the relevant segments and merged them according to their content (e.g., barriers related to the definition of parameters and the quality of the data collected was coded as "lack of data collection skills").

To understand how barriers affect the SCE transition, we placed them in a change management model. We chose Lewin's three-step model [16] because it is well-recognized as the main model compared to other 15 classical change approaches [17]. This model describes the mechanism of change for different social contexts, not only for organizational cases [16,18]. The results are presented in subsections 3.1 and 3.2.

## 3 Results and Discussion

### 3.1 Selected Sample and Identified Barriers

The final result of paper selection consists of 30 publications from 2016 to 2021. Of these articles, 10 were published in 2019 and 12 in 2020. The "Resources, Conservation and Recycling" and "Journal of Cleaner Production" were the most relevant journals, with four and three publications respectively. In half of these articles, the first author is affiliated with an European institution. Survey and interview were the most favourable research method, adopted in 15 articles.

Regarding the barriers to the SCE, we identified 24 relevant barriers that have prevented the transition. To ensure that only relevant barriers were taken for analysis, each barrier should be mentioned at least by three different articles. They were grouped into five categories (see **Fig. 2**): finance, management, infrastructure, network, and technology.

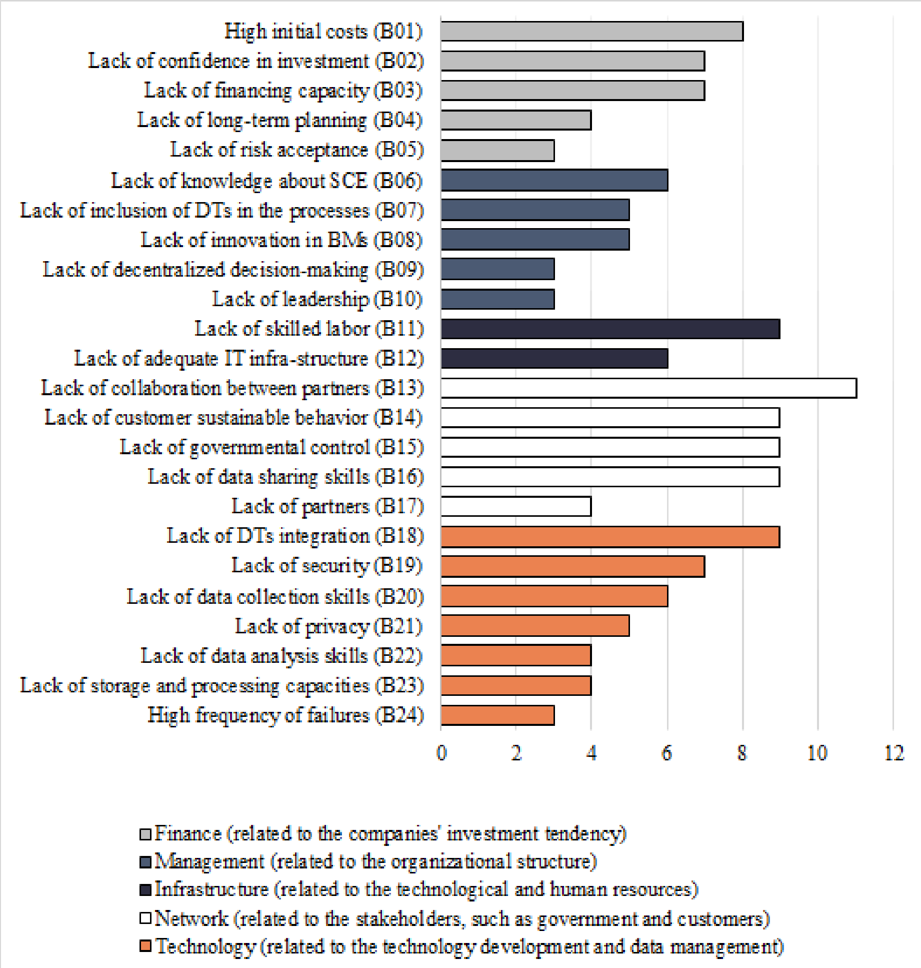


**Fig. 2.** Number of publications per mentioned barrier.

The "network" category is the most mentioned in literature and it indicates that individual goals depend on stakeholders. This finding is in line with the idea that circularity requires a system change, and it cannot be achived by one company alone [19]. Other relevant barriers are lack of skilled labor (B11), a problem that has mainly concerned in emerging markets [20-22], and lack of DTs integration (B18), which is due to the incompatibility of various DTs. A description of each barrier is provided in **Table 1**.

**Table 1.** Barriers to transitioning towards SCE.

| Category | Code | Name | Description | References |
|---|---|---|---|---|
| Finance | B01 | High initial costs | The need to develop technology and skilled labor can lead to prohibitive implementation costs. | 12,21,23-28 |
| | B02 | Lack of confidence in investment | High initial costs and uncertainty about results may cause a lack of confidence at financial return. | 12,22,23,29-32 |
| | B03 | Lack of financing capacity | Budget constraints and lack of funding can limit company investments. | 20,23,25,28,33-35 |
| | B04 | Lack of long-term planning | Lack of immediate results discourages companies focused on short-term profitability. | 22,25,28,32 |
| | B05 | Lack of risk acceptance | Traditional organizations usually avoid innovative projects due to the risk. | 21,36,37 |
| Management | B06 | Lack of knowledge about SCE | As the concept of SCE is not widespread, many companies do not know the opportunities. | 20,23,25,28,33,37 |
| | B07 | Lack of inclusion of DTs in the processes | Lack of digitalization models and knowledge about DTs can lead to processes poorly adapted to the SCE, especially when it envolves human-machine interaction. | 23,26,27,31,3833 |
| | B08 | Lack of innovation in BMs | Due to the lack of creativity and market acceptance, companies find it difficult to redefine the BMs. | 23,27,28,33,39 |
| | B09 | Lack of decentralized decision-making | Hierarchical strucures do not allow decision-making at the operational level, which is necessary in the SCE. | 12,23,35 |
| | B10 | Lack of leadership | Companies do not find experienced and engaged leaders because the concept of SCE is new. | 23,28,35 |
| Infrastructure | B11 | Lack of skilled labor | Due to the lack of knowledge about SCE and the high training costs, organizations lack specialized labor. | 12,20-22,29,34-37 |
| | B12 | Lack of adequate IT infrastructure | Insisting on using old IT infrastructure can lead to implementation and operation problems. | 12,23,26,27,35,37 |
| Network | B13 | Lack of collaboration between partners | Stakeholder competition and lack of coordination may cause poor integration across the product lifecycle. | 20,24,25,28-30,33,35,37,38,40 |
| | B14 | Lack of customer sustainable behavior | Lack of sustainability culture can lead to a lack of sustainable behaviors such as seeking maintenance or separating recyclable waste. | 28-30,31,36,37,39,41,42 |
| | B15 | Lack of governmental control | Outdated laws and unstructured state policies do not stimulate sustainability and digitalization, and even discourage through excessive taxation. | 20,22,24,28,35-37,42,43 |
| | B16 | Lack of data sharing skills | Data sharing is hampered by issues such as information sensitivity, intellectual property, lack of data integrity, and lack of standards for data interoperability. | 27,30,33,37,40,42-45 |
| | B17 | Lack of partners | Lack of suppliers and means of accessing other actors in the supply chain can limit SCE implementation. | 29,35,38,41 |

| | | | | |
|---|---|---|---|---|
| Technology | B18 | Lack of DTs integration | Using multiple technologies and lack of standardization make the DTs' interoperability difficult. | 21,23,24,26-29,32,40 |
| | B19 | Lack of security | Cyber attacks can damage hardware and software, and even make the company vulnerable to blackmailers. | 24,30,32,42,45-47 |
| | B20 | Lack of data collection skills | Lack of experience and skilled labor may cause several difficulties on data collection, such as inappropriate models and data loss. | 8,21,31,34,40,41 |
| | B21 | Lack of privacy | In some applications, it is impossible to guarantee that users are not identifiable. In addition, cyber attacks may also cause information leakage, compromising user privacy. | 8,24,30,46,47 |
| | B22 | Lack of data analysis skills | Analyzes are usually descriptive, but it is not as useful to support decision-making as prescriptive analysis. | 8,23,27,46 |
| | B23 | Lack of storage and processing capacities | Current state of technology development may be insufficient for more demanding applications such as blockchain. | 40,42,46,47 |
| | B24 | High frequency of failures | Sensor malfunctions and communication instabilities can occur at high frequencies and make the use of data unfeasible. | 21,34,37 |

### 3.2 Barriers at Three-Step Change Model

As described in subsection 2.2, we adopted the three-step change model [16] to analyze the barriers. The result is shown in **Fig. 3**.

| Categories of barriers | Unfreeze | Move | Refreeze |
|---|---|---|---|
| Technology | | B18 - Lack of DTs integration<br>B23 - Lack of storage and processing capacities | B19 - Lack of security<br>B20 - Lack of data collection skills<br>B21 - Lack of privacy<br>B22 - Lack of data analysis skills<br>B24 - High frequency of failures |
| Network | B15 - Lack of governmental control | B17 - Lack of partners | B13 - Lack of collaboration between partners<br>B14 - Lack of customer sustainable behavior<br>B16 - Lack of data sharing skills |
| Infra. | | B11 - Lack of skilled labor<br>B12 - Lack of adequate IT infrastructure | |
| Management | B06 - Lack of knowledge about SCE<br>B08 - Lack of innovation in BMs | B07 - Lack of inclusion of DTs in the processes<br>B09 - Lack of decentralized decision-making<br>B10 - Lack of leadership | |
| Finance | B02 - Lack of confidence in investment<br>B04 - Lack of long-term planning<br>B05 - Lack of risk acceptance | B01 - High initial costs<br>B03 - Lack of financing capacity | |
| | Three steps of transition | | |

**Fig. 3.** Barriers to transitioning towards SCE based on the three-step change model.

The first indication of the model is that companies face financial issues mainly in the early steps of change. As small and medium-sized enterprises are more constrained to invest in innovation, they may find it difficult to start the transition [25]. Secondly, the technological barriers emerge mainly in the advanced steps, “move” and “refreeze”. Thus, organizational and strategic aspects of the change may be the most relevant in the current stage of SCE development.

The results also show that the “move” is the most complex step, because companies must deal with problems in all categories. Developing models for this step is a promis-ing research area, because there is a lack of implementation models on CE research [9]. Finally, the “network” category is the only one that influences all change steps. This indicates that stakeholders play a central role in the SCE transition, as discussed in the subsection 3.1. The barriers for each step are explained below.

**Unfreeze.** In the first step of change, the current organization's values and mindset must be reviewed [11]. The resistance to change needs to be overcome [16]. Regarding the transition towards SCE, we identify initial barriers such as lack of long-term planning (B04), risk aversion (B05) and lack of innovation in BMs (B08). Often, the motivation to overcome them comes from external pressures, such as governmental policies (B15).

**Move.** In the second step, the new mindset should be translated into organizational behaviors and capabilities [11]. It requires resources and a planning for change [16,18]. Regarding SCE transition, we identify internal barriers such as lack of leadership (B10), lack of human resources (B11) or IT infrastructure (B12), and the need to adapt the processes (B07). As several SCE strategies require integration throughout the product lifecycle, barriers related to find partners (B17) arise in this step.

**Refreeze.** In the third step, the change must to be consolidated. The organization must incorpore new norms and practices into its culture to avoid regression in the process [16,18]. Regarding SCE transition, the challenges are related to the operation of DTs implemented. Pioneering companies report the need to improve skills in data management (B16, B20, and B22), problems related to technical failures (B24), and security issues (B19), among others.

## 4 Final Remarks

This research contributes to theory and practice of sustainable management by exploring the barriers faced by companies during the transition towards SCE. Through a SLR, we identified the main barriers and separate them into different organizational change steps. The results have implications for public policy, business and academic research.

Our analysis suggests that governments play an important role in stimulating the SCE transition through environmental legislation. However, it can also act on two main issues. First, economic policies can estimulate financing lines for this transformation [20], mainly benefiting small and medium-sized enterprises [25]. Second, educational policies for human resource development can benefit economic development and job creation [20]. These actions may help to overcome barriers B03, B11 and B15.

From the companies' view, aligning digitalization with sustainability is an opportunity for innovation and value creation [48,49]. To get these advantages, managers must carry out a consistent SCE implementation project, taking into account the current and desired state of the company. Our model can be useful for diagnosing the current state and predicting future challenges. We also recommended that firms should develop strategic partners and humans resources to succeed in the transition.

Finally, we suggest that future academic research should focus on solutions to the most relevant problems. CE BMs analyzed by Pieroni et al [9] cover aspects such as knowledge about SCE and innovation, related to the barriers B06 and B08. But our analysis implies that solutions are still needed to estimulate stakeholder cooperation. Promising solutions to increase trust between partners are blockchain technology [32,47] and data marketplaces [44]. These innovations may help to overcome barriers B13 and B17.

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