Prioritization Of Circular Economy Barriers Using Best Worst Method

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Abstract

Circular economy aims to maintain the product value as long as possible. Researches indicate that CE implementation is difficult due to different challenges. In this study, we prioritize CE implementation barriers in order to identify which barriers to deal with first. To achieve this objective, barriers weights are calculated through the Best Worst Method. A systematic literature review is conducted to identify CE challenges. Then, experts from different industrial sectors were called to prioritize these barriers based on their experience. The Best Worst Method Excel solver was used to calculate local and global weight of each challenge. The findings of this study suggest that economic issues are the most significant barriers to CE implementation followed by supply chain management issues, technological, cultural and finally governmental issues. This study aims to help decisions makers from different sectors to prepare their transition to circular flow by defeating main barriers. However, due to the limited considered number of barriers and experts, future research can be extended to more barriers and more experts.

Keywords
Circular Economy, Barriers, BWM, Supply chain and Sustainability.

1. Introduction
Production systems are in a continuous transition to more eco-friendly methods. Environmental treats impose to change vision to how we consume resources (Ulucak et al. 2020). The traditional linear economy (take-make-dispose) consists of extracting virgin raw material, producing, selling and disposing when the product is obsolete. This means that the manufacturer has no strategy on how to handle safely the end-of-life product. In order words, when designing a product, recovery is not considered. Therefore, landfilling and incineration are the product destiny that seriously harms environment and thus society.

In contrast to linear economy, the purpose of circular economy (CE) is to maintain product use as long as possible. CE consists of recovering end-of-life products in order to reuse, remanufacture or recycle. Hence, firstly, waste is managed and minimized and secondly, extraction of virgin material is reduced(Kalmykova et al. 2018) (Garza-Reyes et al. 2019). Circular economy concept makes perfect business sense because it aims to use the value extracted from virgin material several times, not only once (Korhonen et al. 2018).

However, implementation of CE practices in supply chain seems to be difficult for enterprises due to several barriers of different dimensions (Govindan and Hasanagic 2018). In literature, many authors studied the challenges of CE implementation which range from institutional, managerial, technical and social. Nevertheless, the importance of these barriers cannot be the same. Therefore, the identified barriers must be prioritized in order to define a strategy to be

defeated. The purpose of this study is to recognize the main barriers to CE practices in supply chain and classify them. This output gives a hierarchical vision of challenges to face in the most efficient way.

This paper is organized as follows, a literature review is conducted in section 2 to identify previous works related to this topic and also explore the main challenges in the literature. The methodology is detailed in section 3. The results and discussion are presented in section 4. Section 5 summarizes the paper.

2. Literature Review

The literature review is divided into two subsections. First, we present an overview of previous studies on prioritizing CE barriers. Second, we present 20 main barriers extracted from literature review.

2.1 Prioritizing CE barriers in literature

Table 1 shows previous works on CE implementation challenges. The number of considered barriers is from 8 to 36 ones. Almost all barriers are extracted from literature and judged thanks to expert opinions from industrial area or government presenters. This means that expert opinions are affected by the industrial sector they work in. So, they judge according to their sector characteristics. Textile, food and agriculture supply chains are the dominant sectors. As for findings, different barriers are ranked first even though the study is about the same sector. For instance, barriers in food supply chain are studied by three papers. First, Farooque et al. (2019) found that feeble environmental rules, followed by lack of market choice or pressure and lack of cooperation in supply chain are the prominent barriers. While the second paper by Gedam et al. (2021), found that technology and innovation, financial issues are the prominent barriers. The third paper by Liu et al. (2021), states that environmental regulations and education are the key barriers. The most used methods by previous works are AHP or DEMATEL. Prioritizing CE barriers by BWM appear in only two papers with a specific industrial sector. Studying a specific sector provide limited and on-size results. In other words, the given ranking by previous articles cannot be generalized to other sectors. This paper aims to contribute in literature and help other companies to identify the main barriers to defeat for shifting to circular flow. This study aims to address CE implementation challenges in a general way without considering any sector by using Best Worst Method. To achieve this objective, barriers are collected from literature based on rate of appearance and expert are selected from different sectors.

Table 1. previous work on prioritizing CE barriers.

	Number of barriers	Extracted based on	Method	Sector	Results
Khandelwal and Barua (2020)	24	literature review and experts' opinions	Fuzzy AHP	Plastic	Legislative – financial-technological -organizational - market
Chen et al. (2021)	12	literature review and experts' opinions	DEMATEL	Textile	Lack of awareness about CE – absence of good business models- Lack of structure to apply CE model – lack of collaboration
Farooque et al. (2019)	8	literature review and experts' opinions	DEMATEL	Food SC	feeble environmental rules and pressure - lack of market choice/enforcement - absence of cooperation / aid from supply chain
Gedam et al. (2021)	18	literature review and experts' opinions	Fuzzy DEMATEL	Food SC	Absence of technology and innovation – absence of food waste estimation – absence of supply chain optimization – absence of economic profit and great cost of investment
Huang et al. (2021)	12	literature	(FDM), (TISM), MICMAC	Textile	low customer demand for recycled textile products - lack of successful circular business

		review and experts' opinions			models- the challenge of collaborative innovation among supply chain partners - lack of high-quality recycling materials - high costs but low economic benefits in short-term
Haleem et al. (2021)	36	literature review and experts' opinions	fuzzy CRITIC Paetro rule	-	Laws of regulations- Management lack of environmental - lack of financial incentives - higher cost related to recycled material
Kayikci et al. (2021)	34	literature review and experts' opinions	fuzzy DEMATEL	-	lack of governmental support and administrative burden - lack of effective execution of environmental regulations – absence of integration and cooperation among supply chain collaborators - ineffective CE framework adoption - and product complexity for CE
Kazancoglu et al. (2020)	25	literature review and experts' opinions	fuzzy DEMATEL	Textile	Absence of collecting, sorting and recycling for acceptance of CE framework - Uniformity and standardization – absence of technical knowledge
Kazançoğlu et al. (2021)	31	literature review and experts' opinions	Fuzzy BMW and fuzzy VIKOR	Healthcare sector	Managerial – policy - theoretical implementations
P. Kumar et al. (2021)	17	literature review and experts' opinions	Best-Worst Method (BWM)	electric vehicle batteries	Ineffective recycling and reuse of batteries - disposal of batteries - insufficient charging infrastructure
S. Kumar et al. (2021)	11	literature review and experts' opinions	ISM-ANP approach	agriculture	absence of governmental aid and motivation – absence of policies
Liu et al. (2021)	30	List compiled by researcher and reviewed by experts	Fuzzy DEMATEL	agri-food sector	Feeble pressure of environmental rules – absence of environmental awareness and accountability
Mangla et al. (2018)	16	literature review and experts' opinions	MICMAC approach	Automotive manufacturing	Absence of environmental rules- Absence of special tax policies for circular models
Xia and Ruan (2020)	16	literature review and experts' opinions	Gray-DEMATEL	Agriculture	Local officials have weak environmental awareness - Farmers do not make good use of the green financial policy
Zhang et al. (2019)	12	Interviews	Fuzzy DEMATEL	Smart waste management	Absence of expertise and skills for smart waste management – absence of regulatory

					enforcement - absence of environmental defense culture and education

2.2 Barriers of circular economy

The barriers of circular economy implementation were identified by conducting a systematic literature review. Barriers were grouped under various dimensions. Selected barriers are classified into five clusters based on the literature review conducted by (Govindan and Hasanagic 2018). Table 2 presents the barriers of circular economy.

- **Governmental challenges** refer to the absence of standard systems for performance assessment, end-of-policies and organization laws considering CE.
- **Economic challenges** related to financial and funding challenges to implement CE.
- **Technological and skills challenges** refer to limited technological solutions and lower skills to manage effectively a circular flow.
- **culture and social challenges**: refer to lack of public awareness and customer perception to secondhand products.
- **Supply chain management Challenges**: refer to obstacles related to supply chain characteristics and environment.

Table 2: identified barriers of CE from literature.

Dimension	Barriers	Description	Sources
Governmental challenges	**B1**: Lack of governmental policies	Government policies on end-of life strategies (collection and treatment of recyclable materials) are deficient.	Masi et al.(2018), Kumar et al. (2019), Bianchini et al. (2019), Agyemang et al. (2019), Ada et al. (2021), Kirchherr et al. (2018), Akinade et al. (2020), Keulen and Kirchherr (2021)
	B2: Lack of governmental support	Government do not make effort in helping companies to shift to circular flow	Tura et al. (2019), Ada et al. (2021),Mehmood et al. (2021) , Kumar et al. (2019) , de Jesus and Mendonça (2018), Ada et al. (2021), Rizos et al. (2016), Grafström and Aasma (2021)
	B3: Circular economy laws	CE laws are not powerful and most of them are not elaborated based on technical knowledge.	Mehmood et al.(2021), Kumar et al. (2019) , Bianchini et al. (2019), Grafström and Aasma (2021)
Economic challenges	**B4**: Weak economic incentives	Integration of circular economy must be supported by economic incentive such as minimizing taxation.	Mehmood et al. (2021), Masi et al. (2018), Kumar et al.(2019) , Ada et al. (2021), Grafström and Aasma (2021)
	B5: Investment cost	Implementation of circular economy need a high start-up investment.	Govindan and Hasanagic (2018), de Jesus and Mendonça (2018), Mehmood et al. (2021), Masi et al. (2018), Jaeger and Upadhyay (2020), Agyemang et al. (2019), Kirchherr et al. (2018), Rizos et al. (2016), Grafström and Aasma (2021)
	B6: Cost of recycled materiel	Recycled material cost is higher than Virgen material cost	Mehmood et al. (2021), Masi et al. (2018), Kumar et al. (2019), Jaeger and Upadhyay (2020), Kirchherr et al. (2018), Grafström and Aasma (2021)
	B7: Absence of tools to quantify (long-term) profits of CE projects	There are no tools which can measure and convince decision maker to advantageous outcomes of CE implementation.	Tura et al. (2019), de Jesus and Mendonça (2018), Ritzén and Sandström (2017), Mehmood et al. (2021)

Technological and skills challenges	**B8**: Design challenge	CE impose to product designer to be creative and produce a product which can be recovered.	Mehmood et al. (2021), Kumar et al. (2019), Jaeger and Upadhyay (2020), Bianchini et al. (2019), Kirchherr et al. (2018), Grafström and Aasma (2021)
	B9: Quality of reused product	Maintaining the quality of product manufactured by reused materiel.	Govindan and Hasanagic (2018), Ritzén and Sandström (2017), Ada et al. (2021) Jaeger and Upadhyay (2020), (Bianchini et al., 2019), Kirchherr et al. (2018), Grafström and Aasma (2021)
	B10: Lack of real time data	Unavailable technological tools providing accurate information.	Vikas Kumar et al. (2019), Govindan and Hasanagic (2018)
	B11: Lack of advanced technologies and equipment	CE implementation need more cutting-edge technologies, machine, procedure, …	de Jesus and Mendonça (2018), Mehmood et al. (2021), Vikas Kumar et al. (2019), Bianchini et al. (2019), Agyemang et al. (2019), Grafström and Aasma (2021), Akinade et al. (2020)
	B12: Lack technical skills	Human resources are not technically formed to work under CE framework.	Tura et al. (2019), de Jesus and Mendonça (2018), Mehmood et al.(2021), Kumar et al. (2019), Jaeger and Upadhyay (2020), Bianchini et al. (2019), Agyemang et al. (2019), Rizos et al. (2016), Grafström and Aasma (2021)
Culture and social challenges	**B13**: Lack of public awareness	Citizens are not aware of environmental treats and thus not interesting in CE drivers.	Govindan and Hasanagic (2018), Tura et al. (2019) , Vikas Kumar et al. (2019), Ada et al. (2021), Grafström and Aasma (2021),
	B14: Insufficient motivation for the circular economy	Industries are not interested in establishing an eco-industrial chain and prefer the linear flow.	Mehmood et al. (2021), Masi et al.(2018), Grafström and Aasma (2021)
	B15: Consumer perception to reused product	Customer think usually that second hand product are poor or low quality.	Govindan and Hasanagic (2018), de Jesus and Mendonça (2018), Bianchini et al. (2019), Agyemang et al. (2019), Kirchherr et al.(2018), Grafström and Aasma (2021)
Supply chain management challenges	**B16**: Challenge of take back from other companies	Difficulty in making a deal to exchange waste or recycled materiel	Govindan and Hasanagic (2018), Mehmood et al.(2021)
	B17: Higher priority of other issues	Manager are more interested in other supply chain problems such as production expansion/market, …	Ada et al. (2021), Govindan and Hasanagic (2018)
	B18: Poor leadership and management towards CE in SC	Limited top management support for sustainability actions decreases the interest in circular economy	Agyemang et al. (2019), Govindan and Hasanagic (2018)
	B19: Lack of collaboration	Difficulty of sharing information between companies in supply chain	Ritzén and Sandström. (2017), Masi et al. (2018), Jaeger and Upadhyay (2020), Bianchini et al.(2019), Agyemang et al. (2019), Ada et al. (2021), Kirchherr et

			al.(2018), Rizos et al.(2016), Grafström and Aasma (2021), Keulen and Kirchherr (2021)
	B20: Return rate uncertainty	End-of-life strategies do not ensure a stable and a certain return of product.	Mehmood et al. (2021)

3. Method

The objective of this study is to prioritize the key barriers to circular economy implementation in supply chain. The methodology of this study is shown in Figure 1. First, we look for the most relevant circular economy implementation barriers from literature presented in Table 2. Then we classify them into five clusters: governmental, economic, technological, culture and supply chain management. In order to identify importance of each barrier, we contacted 8 experts based on their years of experience and their position in the company. Details about experts are presented in Table 3. To collect their opinions, an online survey was addressed and transferred to them. The purpose of the survey was to make comparisons. As we have more than 9 barriers, it was necessary to make several comparisons. First, experts had to choose the most and least important of the clusters mentioned before and then compare them on a scale of 1-9 with other clusters. Results are shown in Tables 4 and 5. Second, they do the same for the sub-criteria of each cluster by comparing most and least important barriers with other barriers. Once we receive experts' responses, we start our analysis. We used the Best worst method Excel solver to calculate the weight of each barrier. Results are shown in Table 6. Local weight refers to the weight of each barrier compared to other barriers of the same cluster. Meanwhile global weight refers to the weight of each barrier compared to all identified barriers. Finally, we ranked challenges according to their local and global weight. Reader is referred to Table 7. The average of Ksi (**0,0839087**) indicator near to zero proves the reliability of consistent comparisons.

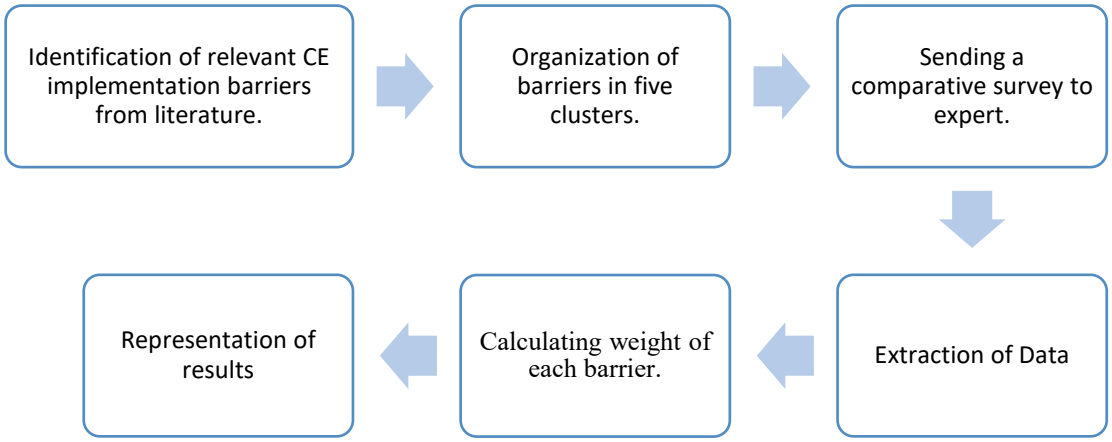

Figure 1. Methodology of this study

3.1 Best Worst Method

Due to their complexity, real-world problems must be analyzed through several criteria to make optimal decisions. Multi-criteria decision-making tools and methodologies are important fields in operations research. They offer decision support to conflicting objectives or complex issues with multiple criteria. MCDM problems are fractionated into two categories. When a decision-maker has to evaluate and classify alternatives from best to worst, we talk about discrete MCDM which can be addressed through multi-attribute decision making (MADM) methods. While multi-objective decision-making (MODM) methods address continuous MCDM (Kahraman et al.2015). The best worst method (BWM) is a multi-criteria decision-making method proposed by (Rezaei 2015). In contrast with other MCDM tools, BMW needs fewer comparisons and provides reliable and harmonious outcomes. It consists of five mathematical steps:

Step 1: identify the supply chain barriers to implement circular economy through literature review.
Step 2: identify the most important and influencing barrier (best) and the least important and influencing barrier (worst) by expert.

Step 3: determine the preference of the most important challenge over the other challenges on a scale of 1 to 9 and then construct the Best-to-Others vector.
Step 4: determine the preference of the least important challenge over the other challenges on a scale of 1 to 9 and then construct the other-to-worst vector.
Step 5: determine the optimal weight of each barrier.

Table 3. Experts of decision panel

	Position	Years of experience
Expert 1	Project Manager	7
Expert 2	Project Manager	12
Expert 3	Consulting engineer	37
Expert 4	Businessman	18
Expert 5	Consultant	5
Expert 6	Engineer	21
Expert 7	Director	25
Expert 8	Manager	20

4. Results and Discussion

The present study highlights the importance of circular economy implementation challenges by calculating their weights through the best-worst method. The weight is calculated based on experts' opinions on the importance of each barrier. As shown in Table 7, the results revealed that among the major criteria; economic issues hold the highest weight (**0,26913724),** followed by supply chain management issues (**0,26060876),** Technological issues (**0,17483349**), Cultural and social issues (**0,15554972**), and finally governmental issues (**0,13987078**). These findings indicate that both economic and supply chain management issues are seen as the obstructive barriers in restricting circular economy adoption. Therefore, evolving toward a circular flow means that companies have to defeat financial barriers and also supply chain management problems. Technological issues come third, which means that once economic and supply chain management barriers are defeated, technological problems can be solved. A local importance discussion is carried in following.

Among the economic cluster, results show that weak economic incentives is the most significant challenge, followed by the expected investment cost, lack of tools to estimate CE implementation benefits and the higher cost of recycled material. In other words, to begin a CE project companies must receive encouraging economic incentives (Govindan and Hasanagic 2018). Investment cost always looks greater for stakeholders. However, if we defeat the third barrier and provide a powerful tool to estimate the CE implementation benefits, the second challenge can be defeated. Fourth, experts indicate that virgin raw material cost still less than cost of recycled material. As cost is the most attractive for companies, recycled material must be sold at a less price.

Among the supply chain management issues, the challenge of take-back from other companies is the most significant barrier. Followed by higher importance of other issues, feeble leadership, return rate uncertainty and absence of cooperation. The complexity of supply chain makes it difficult to implement CE. This study shows that before evolving towards a circular flow, all supply chain operators must build a powerful collaboration. This means, a partnership able to develop sustainably by having same priorities and sharing accurate information (Duong and chong 2020).

Among Technological issues, Lack of real-time data comes first followed by lack of advanced technologies and equipment, lack of technical skills, design challenge and quality of reused product. Before CE implementation, accurate data must be available. Companies must invest in new and friendly technologies. Moreover, employees must develop their skills, so they can produce more sustainability and use advanced technologies(Bonekamp and Sure2015). Redesigning the product must take place to manage the end-of-life strategies. Finally, quality has to be maintained.

Among the cultural and social issues, Lack of public awareness is the most important, followed by Customer perception toward secondhand products and Lack of enthusiasm toward CE. Customer awareness is an important factor to implement sustainability in supply chain (Gong et al., 2019). Hence, he must encourage this transition toward circular flow by buying secondhand products and changing the negative vision.

Among governmental issues, absence of governmental aid, Lack of governmental policies and absence of circular economy laws. Government has to initiate this sustainable project, by supporting companies to shift toward CE and developing policies to identify end-of-life strategies (Araujo Galvão et al., 2018). CE laws must be developed. Even if governmental issues obtained the last weight, Governmental support and policies are ranked in 7 and 8 places for global weight. This means that companies need governmental support for effective collaboration. The numerical results for Bes-to-Others vector and Others to best vectors are tabulated in the below Table 4 and Table 5 respectively.

4.1 Numerical Results

Table 4. Best-to-Others vector.

	Best	**Governmental challenges**	**Economic challenges**	**Technological challenges**	**Cultural and social challenges**	**SC management challenges**
Expert 1	SC management challenges	9	5	4	3	1
Expert 2	Economic challenges	4	1	9	4	3
Expert 3	SC management challenges	9	1	9	5	1
Expert 4	Technological challenges	3	4	1	8	5
Expert 5	Economic challenges	5	1	6	9	3
Expert 6	SC management challenges	5	3	9	3	1
Expert 7	Cultural and social challenges	8	5	2	1	6
Expert 8	Governmental challenges	1	3	2	7	4

Table 5. Others-to-Worst vector.

	Worst	Governmental challenges	Economic challenges	Technological challenges	Cultural and social challenges	SC management challenges
Expert 1	Governmental challenges	1	3	5	3	9
Expert 2	Technological challenges	4	9	1	3	3
Expert 3	Technological challenges	1	9	1	5	9
Expert 4	Cultural and social challenges	6	5	8	1	3
Expert 5	Cultural and social challenges	4	9	3	1	6
Expert 6	Technological challenges	3	3	1	8	9
Expert 7	Governmental challenges	1	3	6	8	3
Expert 8	Cultural and social challenges	8	5	7	1	3

Table 6. Major criteria weights.

	Governmental challenges	Economic challenges	Technological challenges	Cultural and social challenges	SC management challenges	ksi
Expert 1	0,045965271	0,11644535	0,145556691	0,194075587	0,497957099	0,084269663
Expert 2	0,137466307	0,49326146	0,04851752	0,137466307	0,18328841	0,056603774
Expert 3	0,03597944	0,40605368	0,054254712	0,097658481	0,406053684	0,082238721
Expert 4	0,196078431	0,14705882	0,490196078	0,049019608	0,117647059	0,098039216
Expert 5	0,122211445	0,52376334	0,101842871	0,048496605	0,203685742	0,087293889
Expert 6	0,115384615	0,19230769	0,038461538	0,192307692	0,461538462	0,115384615
Expert 7	0,051679587	0,10852713	0,271317829	0,478036176	0,090439276	0,064599483
Expert 8	0,414201183	0,16568047	0,24852071	0,047337278	0,124260355	0,082840237
Average	**0,13987078**	**0,26913724**	**0,17483349**	**0,15554972**	**0,26060876**	**0,0839087**

Table 7 Final ranking of sustainable manufacturing barriers

Cluster	Major Weight	Barrier	Local Weight	Local rank	Global Weight	Global Rank
Governmental issues	0,13987078	**B1**: Lack of governmental policies	0,382202163	2	0,059024259	7
		B2: Lack of governmental support	0,43104243	1	0,052610001	8
		B3: Circular economy laws	0,186755407	3	0,028236526	16
Economic issues	0,26913724	**B4**: Weak economic incentives	0,326408179	1	0,095926378	4
		B5: Investment cost	0,315161624	2	0,098345855	3
		B6: Cost of recycled materiel	0,15515914	4	0,034092226	11
		B7: Absence of tools to quantify (long-term) profits of CE projects	0,203271057	3	0,040772785	9
Technological issues	0,17483349	**B8**: Design challenge	0,176352549	4	0,028454063	15
		B9: Quality of reused product	0,150379681	5	0,022902229	20
		B10: Lack of real time data	0,257526555	1	0,067668668	5
		B11: Lack of advanced technologies and equipment	0,21745764	2	0,030584516	13
		B12: Lack technical skills	0,198283575	3	0,025224018	18

Cultural and social issues	0,15554972	**B13**: Lack of public awareness	0,641737592	1	0,10067089	2
		B14: Insufficient motivation for the circular economy	0,154140182	3	0,024792855	19
		B15: Consumer perception to reused product	0,204122226	2	0,030085972	14
SC management issues	0,26060876	**B16**: Challenge of take back from other companies	0,364979165	1	0,104549947	1
		B17: Higher priority of other issues	0,200782729	2	0,061560915	6
		B18: Poor leadership and management towards CE in SC	0,188510546	3	0,032466773	12
		B19: Lack of collaboration	0,115309738	5	0,027032381	17
		B20: Return rate uncertainty	0,163550352	4	0,034998744	10

5. Conclusion

The objective of this research is to prioritize challenges to circular economy implementation. Since challenges cannot be defeated once, a hierarchical vision of these challenges allows companies to go step by step in this sustainable project. We used the best-worst method based on the opinion of experts to prioritize barriers. Based on our results, the major barriers are related to financial challenges and supply chain management. Weak economic incentives, investment cost and lack of collaboration through the supply chain are the most relevant barriers that must be defeated. First, companies have to maintain enough funds before implementing CE. Government and other organizations must support companies to shift toward circular flow. Second, Supply chain partners must develop a good collaboration based on the same objectives to ensure extracting value from material several times. Third, companies need to have access to accurate data and advanced technologies at a reasonable cost. Also, the training centers must focus on developing employ's skills. Customer and society must be aware of environmental threats and encourage producers to provide more eco-friendly products.

This study has some limitations. Barriers are extracted from literature and the number of experts is only 8. For future research, authors can investigate more barriers by interviewing industrial actors. Also, the number of experts can be extended.

References

Ada, N., Kazancoglu, Y., Sezer, M. D., Ede-Senturk, C., Ozer, I. and Ram, M., Analyzing Barriers of Circular Food Supply Chains and Proposing Industry 4.0 Solutions, *Sustainability*, vol. **13**, no. 12, pp. 6812, 2021.

Agyemang, M., Kusi-Sarpong, S., Khan, S. A., Mani, V., Rehman, S. T. and Kusi-Sarpong, H., Drivers and Barriers to Circular Economy Implementation: An Explorative Study in Pakistan's Automobile Industry, *Management Decision*, vol. **57**, no. 4, pp. 971–94, April 18, 2019.

Akinade, O., Oyedele, L., Oyedele, A., Davila Delgado, J. M., Bilal, M., Akanbi, L., Ajayi, A. and Owolabi, H., Design for Deconstruction Using a Circular Economy Approach: Barriers and Strategies for Improvement, *Production Planning & Control*, vol. **31**, no. 10, pp. 829–40, 2020.

Araujo Galvão, G. D., Nadae, J. de, Clemente, D. H., Chinen, G. and Carvalho, M. M. de, Circular Economy: Overview of Barriers, *Procedia CIRP*, vol. **73**, pp. 79–85, 2018.

Bianchini, Rossi, and Pellegrini, Overcoming the Main Barriers of Circular Economy Implementation through a New Visualization Tool for Circular Business Models, *Sustainability*, vol. **11**, no. 23, p. 6614, 2019.

Bonekamp, L. and Sure, M., Consequences of Industry 4.0 on Human Labour and Work Organisation, *Journal of Business and Media Psychology*, vol. **6**, no. 1, pp. 33–40, 2015.

Chen, W.-K., Nalluri, V., Hung, H.-C., Chang, M.-C. and Lin, C.-T., Apply DEMATEL to Analyzing Key Barriers to Implementing the Circular Economy: An Application for the Textile Sector, *Applied Sciences*, vol. **11**, no. 8, p. 3335, 2021.

Duong, L. N. K. and Chong, J., Supply Chain Collaboration in the Presence of Disruptions: A Literature Review, *International Journal of Production Research*, vol. **58**, no. 11, pp. 3488–3507, 2020.

Farooque, M., Zhang, A. and Liu, Y., Barriers to Circular Food Supply Chains in China, *Supply Chain Management: An International Journal*, vol. **24**, no. 5, pp. 677–96, 2019.

Garza-Reyes, J. A., Kumar, V., Batista, L., Cherrafi, A. and Rocha-Lona, L., From Linear to Circular Manufacturing Business Models, *Journal of Manufacturing Technology Management*, vol. **30**, no. 3, pp. 554–60, 2019.

Gedam, V. V., Raut, R. D., Lopes de Sousa Jabbour, A. B., Tanksale, A. N. and Narkhede, B. E., Circular Economy Practices in a Developing Economy: Barriers to Be Defeated, *Journal of Cleaner Production*, vol. **311**, p. 127670, 2021.

Gong, M., Gao, Y., Koh, L., Sutcliffe, C. and Cullen, J., The Role of Customer Awareness in Promoting Firm Sustainability and Sustainable Supply Chain Management, *International Journal of Production Economics*, vol. **217**, pp. 88–96, 2019.

Govindan, K. and Hasanagic, M., A Systematic Review on Drivers, Barriers, and Practices towards Circular Economy: A Supply Chain Perspective, *International Journal of Production Research*, vol. **56**, no. 1–2, pp. 278–311, 2018.

Grafström, J. and Aasma, S., Breaking Circular Economy Barriers, *Journal of Cleaner Production*, vol. **292**, pp. 126002, 2021.

Haleem, A., Khan, S., Pundir, H., Jain, A., Upadhyay, P. and Khan, M. I., Investigating Barriers Toward the Implementation of Circular Economy: A Fuzzy CRITIC Approach, *Journal of Industrial Integration and Management*, vol. **06**, no. 01, pp. 107–39, 2021.

Huang, Y.-F., Azevedo, S. G., Lin, T.-J., Cheng, C.-S. and Lin, C.-T., Exploring the Decisive Barriers to Achieve Circular Economy: Strategies for the Textile Innovation in Taiwan, *Sustainable Production and Consumption*, vol. **27**, pp. 1406–1423, 2021.

Jaeger, B. and Upadhyay, A., Understanding Barriers to Circular Economy: Cases from the Manufacturing Industry, *Journal of Enterprise Information Management*, vol. **33**, no. 4, pp. 729–745, 2020.

Jesus, A. de and Mendonça, S., Lost in Transition? Drivers and Barriers in the Eco-Innovation Road to the Circular Economy, *Ecological Economics*, vol. **145**, pp. 75–89, 2018.

Kahraman, C., Onar, S. C. and Oztaysi, B., Fuzzy Multicriteria Decision-Making: A Literature Review, *International Journal of Computational Intelligence Systems*, vol. **8**, no. 4, pp. 637, 2015.

Kalmykova, Y., Sadagopan, M. and Rosado, L., Circular Economy – From Review of Theories and Practices to Development of Implementation Tools, *Resources, Conservation and Recycling*, vol. **135**, pp. 190–201, 2018.

Kayikci, Y., Kazancoglu, Y., Lafci, C. and Gozacan, N., Exploring Barriers to Smart and Sustainable Circular Economy: The Case of an Automotive Eco-Cluster, *Journal of Cleaner Production*, vol. **314**, pp. 127920, 2021.

Kazancoglu, I., Kazancoglu, Y., Kahraman, A., Yarimoglu, E. and Soni, G., Investigating Barriers to Circular Supply Chain in the Textile Industry from Stakeholders' Perspective, *International Journal of Logistics Research and Applications*, pp. 1–28, 2020.

Kazançoğlu, Y., Sağnak, M., Lafcı, Ç., Luthra, S., Kumar, A. and Taçoğlu, C., Big Data-Enabled Solutions Framework to Overcoming the Barriers to Circular Economy Initiatives in Healthcare Sector, *International Journal of Environmental Research and Public Health*, vol. **18**, no. 14, pp. 7513, 2021.

Keulen, M. van and Kirchherr, J., The Implementation of the Circular Economy: Barriers and Enablers in the Coffee Value Chain, *Journal of Cleaner Production*, vol. **281**, 2021.

Khandelwal, C. and Barua, M. K., Prioritizing Circular Supply Chain Management Barriers Using Fuzzy AHP: Case of the Indian Plastic Industry, *Global Business Review*, pp. 097215092094881, 2020.

stense-Smit, E., Muller, J., Huibrechtse-Truijens, A. and Hekkert, M., Barriers to the Circular Economy: Evidence From the European Union (EU), *Ecological Economics*, vol. **150**, pp. 264–272, 2018.

Korhonen, J., Honkasalo, A. and Seppälä, J., Circular Economy: The Concept and Its Limitations, *Ecological Economics*, vol. **143**, pp. 37–46, 2018.

Kumar, P., Singh, R. K., Paul, J. and Sinha, O., Analyzing Challenges for Sustainable Supply Chain of Electric Vehicle Batteries Using a Hybrid Approach of Delphi and Best-Worst Method, *Resources, Conservation and Recycling*, vol. **175**, pp. 105879, 2021.

Kumar, S., Raut, R. D., Nayal, K., Kraus, S., Yadav, V. S. and Narkhede, B. E., To Identify Industry 4.0 and Circular Economy Adoption Barriers in the Agriculture Supply Chain by Using ISM-ANP, *Journal of Cleaner Production*, vol. **293**, pp. 126023, 2021.

Kumar, V., Sezersan, I., Garza-Reyes, J. A., Gonzalez, E. D. R. S. and AL-Shboul, M. A., Circular Economy in the Manufacturing Sector: Benefits, Opportunities and Barriers, *Management Decision*, vol. **57**, no. 4, pp. 1067–1086, 2019.

Liu, Y., Wood, L. C., Venkatesh, V. G., Zhang, A. and Farooque, M., Barriers to Sustainable Food Consumption and Production in China: A Fuzzy DEMATEL Analysis from a Circular Economy Perspective, *Sustainable Production and Consumption*, vol. **28**, pp. 1114–1129, 2021.

Mangla, S. K., Luthra, S., Mishra, N., Singh, A., Rana, N. P., Dora, M. and Dwivedi, Y., Barriers to Effective Circular Supply Chain Management in a Developing Country Context, *Production Planning & Control*, vol. **29**, no. 6, pp. 551–569, 2018.

Masi, D., Kumar, V., Garza-Reyes, J. A. and Godsell, J., Towards a More Circular Economy: Exploring the Awareness, Practices, and Barriers from a Focal Firm Perspective, *Production Planning & Control*, vol. **29**, no. 6, pp. 539–550, 2018.

Mehmood, A., Ahmed, S., Viza, E., Bogush, A. and Ayyub, R. M., Drivers and Barriers towards Circular Economy in Agri-food Supply Chain: A Review, *Business strategy & development*, pp. 1-17, 2021.

Rezaei, J., Best-Worst Multi-Criteria Decision-Making Method, *Omega*, vol. **53**, pp. 49–57, 2015.

Ritzén, S. and Sandström, G. Ö., Barriers to the Circular Economy – Integration of Perspectives and Domains, *Procedia CIRP*, vol. **64**, pp. 7–12, 2017.

Rizos, V., Behrens, A., Gaast, W. van der, Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., et al., Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers, *Sustainability*, vol. **8**, no. 11, pp. 1212, 2016.

Tura, N., Hanski, J., Ahola, T., Ståhle, M., Piiparinen, S. and Valkokari, P., Unlocking Circular Business: A Framework of Barriers and Drivers, *Journal of Cleaner Production*, vol. **212**, pp. 90–98, 2019.

Ulucak, R., Danish and Ozcan, B., Relationship between Energy Consumption and Environmental Sustainability in OECD Countries: The Role of Natural Resources Rents, *Resources Policy*, vol. **69**, pp. 101803, 2020.

Xia, X. and Ruan, J., Analyzing Barriers for Developing a Sustainable Circular Economy in Agriculture in China Using Grey-DEMATEL Approach, *Sustainability*, vol. **12**, no. 16, pp. 6358, 2020.

Zhang, A., Venkatesh, V. G., Liu, Y., Wan, M., Qu, T. and Huisingh, D., Barriers to Smart Waste Management for a Circular Economy in China, *Journal of Cleaner Production*, vol. **240**, pp. 118198, 2019.

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