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Challenges in Applying Circular Economy Concepts to Food Supply Chains

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Abstract: In recent years, Circular Economy (CE) has captured vast global attention with regard to its potential in mitigating contemporary economic, social, and environmental challenges. This study aims to present the barriers that impede the application of CE concepts in the food supply chain (FSC) which received limited literature recognition. A systematic literature review is utilized to scrutinize challenges, resulting in 17 factors that burden CE adoption. The challenges were categorized under six subsets and were prioritized based on two perspectives: literature importance and empirical importance. A combination of literature frequency analysis and Field-Weighted Citation Impact was employed to derive the rankings related to literature importance. The pragmatic importance of challenging factors is derived using the Fuzzy Best-Worst method. Both rankings reveal that cost efficiency consideration is the most critical barrier that hinders the transition to CE in FSC. Thus, this paper highlights similarities and differences in the perspectives of academia and practicality by comparing the two prioritizations. The findings can be used to remove obstacles, create policies and strategies, and assist governments in implementing circular practices throughout FSC.

Keywords: circular economy; sustainability; literature review; frequency analysis; fuzzy best-worst method; food supply chain

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1. Introduction

The world's population is growing rapidly, and it is anticipated to reach 9.8 billion by 2050 [1]. Thus, food production is obligated to feed an additional two billion people within 30 years and will surge the food requirement by 70% [2]. Bastein et al. [1] confirmed that the fulfillment of future food demand is impossible with existing scarce resources, and it will ultimately declare greater pressure on the environment. Even today, the implications of the food system have resulted in an 80% loss of biodiversity while contributing to one-third of greenhouse gas emissions [2]. Food loss and waste is another prominent flaw in the food chain as one-third of consumable food production is estimated to be lost or discarded in the supply chain, equivalent to 1.3 billion tons per year [3]. On the contrary, around 10.7% of the global population is suffering from hunger [4]. Hence, the current food supply chain (FSC) confronts the contemporary trilemma of food security and scarcity, environmental degradation, and food loss and waste that require urgent sustainable remedies.

Experts in the food system are intrigued by the concept of the Circular Economy (CE) as a potential response to all the uncertainties and difficulties that lie ahead [5,6]. CE is a sustainable paradigm that aims to build a system that is regenerative and restorative by design [7,8]. In the CE, the 'take-make-waste' model of linear economy is replaced by the concepts of reducing, repairing, reusing, refurbishing, remanufacturing, and recycling, leading to zero or little waste generation. CE in the FSC can be stated as reducing food waste generated by various tiers in the food chain, utilizing by-products and food waste, recycling nutrients, reusing packaging, and making dietary adjustments that have a lower environmental impact [9]. On top of that, CE adoption is estimated to generate an annual economic value of 1.8 trillion EUR by 2030. As a result, the transition towards CE will be cost-effective while also contributing to environmental preservation and societal concerns.

However, since the existing approach is based on a resource-centric linear economy, the transition to CE encounters significant challenges. These impediments hinder businesses from making the switch to circularity [10,11]. Therefore, Agyemang et al. [12] stated that identifying and removing barriers to CE adoption will perform as the primary driver for CE application in supply chains. We aim to approach that point of identifying challenging factors that impede the CE transition, particularly in FSC as a solid foundation for eliminating the extant trilemma of the food system through this study.

As authors have recognized the importance of this concern, the previous academic literature consists of several barrier analyses of CE adoption concerning various supply chains and supply chain procedures. Farooque et al. [13], Mangla et al. [14], Masi et al. [15], and Tura et al. [16] explored descriptive lists of challenges from a general supply chain perspective. As the authors understood the importance of specifying particular supply chains, Farooque et al. [17] focused on determining barriers in FSC in the Chinese context as FSC has its unique vulnerabilities [18]. Following that, Sharma et al. [19] probed in the Indian context where FSCs are more complex and irregular. Despite recent enthusiasm for changes to CE adoption in FSC, Farooque et al. [17] concluded that the literature lacks a comprehensive list of challenging factors specified for FSC universally. Therefore, we designed our study based on the pronounced academic gap to contribute to implementing circularity in sustainable food chains. Throughout our study, we seek to fulfill several knowledge disparities by following the research objectives stated below:

RO1. Identify challenges to applying CE in the FSC from existing research
RO2. Categorize and rank the challenges based on literature appearance
RO3. Systematically analyze and prioritize challenges based on expert opinions
RO4. Compare and contrast the differences between literature ranking and experiential rankings

Our work offers important insights about barriers to CE transition in FSC that are derived through a systematic literature review to bridge the knowledge gap. Previous studies have analyzed the factors by employing various techniques [10,17,19]. As per the authors' best knowledge, this study is the initial work that attempts to compare the challenges of prioritization considering literature importance and empirical importance. We utilized literature frequency analysis combined with article-level citation metric to develop literature importance and the Fuzzy Best-Worst method (FBWM) which is a novel multi-criteria decision analysis tool [20] for empirical importance derivation. By incorporating a literature review and professionals' opinions into our work, we intend to point out the similarities and differences between literature and practical prioritizations and attention to different challenging factors as a vital contribution to CE transition in the food system. Thus, we present a preliminary research contribution work in terms of developing an exhaustive list of barriers that hinder applying CE in FSC and comparing the literature and pragmatic importance of barriers.

The remainder of the paper is structured as follows: Section 2 discusses the research background of the discipline. Section 3 depicts the methodology adopted to identify, categorize, and rank the challenging factors and the rationale behind selecting those techniques. Research findings, analysis, and discussion are elaborated in Section 4. Section 5 provides industrial implications, research limitations, and future directions. At last, the conclusion of the paper is depicted in Section 6.

2. Background

The broad literature on food circularity consists of diverse sectors and value chains considered for the transition. For instance, Borrello et al. [21] focused on the agri-food industry in the Netherlands to apply CE framework and identified several challenges in conceptual CE framework adoption. The cooking oil industry in the UK is explored by incorporating a hybrid Life Cycle Assessment (LCA) model to derive the emissions, waste, and carbon footprint of the industry [22]. Similarly, the LCA model has been widely used in the literature to bracket out the impacts of extant practices and the influence of circularity [5,10]. Not only food production and processing, but food packaging and distribution have caught the eye of researchers as the impact of the outbound supply chain is significant. The impact of food packaging that affects the lifetime of food and food waste is investigated by Pauer et al. [23]. Kazancoglu et al. [24] employed system dynamics to investigate the performance appraisal of reverse logistics in FSC. In addition, consumer acceptance and behavior on circular food production and similar research on the consumption stage are covered in the literature [25].

The contemporary trilemma faced by FSC has aroused the requirement of reflection on sustainable development attached to CE. Therefore, the importance of CE concepts with regard to sustainable development is broadly investigated throughout the literature [9,26–29]. Sauvé et al. [26] described the relationship between CE and sustainable development as these concepts respectively follow bottom-up and top-down approaches and intersect clearly. Adding to that, since CE concepts in FSC concentrate on minimizing food waste and boosting sustainability, initially it helps to achieve sustainable development goals (SDGs) such as responsible consumption and production (SDG 12) [27], zero hunger (SDG 2) [22], and climate action (SDG 13) [9]. Further, adopting CE concepts indirectly induces good health and well-being (SDG 3), clean water and sanitation (SDG 6), industry, innovation and infrastructure (SDG 9), life below water (SDG 14), and life on land (SDG 15) [27,30,31].

CE concept adopts the processes in the supply chain in contrast to the linear economy where the waste is directly discarded from the value chain. In CE, the term 'waste' implies a contradictory meaning to the traditional junk; in lieu, it means underutilization of resources and assets according to the Circular Economy Symposium held in India [32]. Despite the criticality of CE application in FSCs, it encounters various challenges along the way of transitioning to CE [33]. Jurgilevich et al. [9] emphasized that identifying and removal of barriers that act against CE transition is a key driving factor for implementing circular practices.

There are a few studies that touched on CE application in FSCs as adopting CE is described as a technique for uplifting the efficiencies in the food system while optimizing the resources in the value chain [17]. Mostly, the scope of those studies is limited or concentrated to a particular stage in the supply chain. Table 1 stipulates the existing studies that addressed the FSCs in diverse areas, the focused country of the study, and the limitations encountered in the exploration.

The extant research lacks an exhaustive literature review on CE barriers for adoption in FSC, classification, prioritization, and comparisons of literature and empirical rankings. Even though past studies have used different methodologies to prioritize the challenges for application, neither study compares the acceptability of factors among scholars with the prioritization of decision-making techniques. In this paper, we attempt to bridge the current apertures in the research field by conducting a systematic literature review to derive a comprehensive list of challenging factors. Further, we systematically categorize and prioritize the identified factors based on their literature and pragmatic importance. Finally, we compare the two prioritizations of barrier importance in terms of CE transition in FSC.

Table 1. Extant literature on barrier identification studies for CE adoption in FSC.

Authors and Year	Focused Area of Study	Focused Country	Limitations of the Study
Kasim and Ismail [34]	Restaurant chain	Malaysia	Only considered environmental sustainability aspect
Borrello et al. [21]	Bread FSC	Netherlands	Limited scope
Farooque et al. [17]	Not specified	China	Barrier identification is not exhaustive Limited barriers No categorization of barriers
Sharma et al. [19]	Dairy FSC	India	The list of identified challenges is not comprehensive Challenges are not categorized
Dossa et al. [35]	Wheat FSC	UK	Challenges identification scope is limited
Garske et al. [36]	Food loss and waste stage	European Union	Determined challenges concern legislation application; limited challenges definition
Taghiye et al. [37]	Agri-FSC	Azerbaijan	Limited barriers are identified
Xia and Ruan [38]	Agri-FSC	China	Considered only the agricultural sector in the study
Kumar et al. [39]	Agri-FSC	India	Limited to the agri-food industry and focused on challenges to adopting CE related to industry 4.0
Gedam et al. [10]	Not specified	India	The list of identified challenges is not comprehensive

3. Methodology

This section is laid as follows: we discuss how the challenges to adopting CE in the FSC can be identified and categorized in Section 3.1. We then discuss barrier prioritization techniques where the literature importance-based approaches are presented in Section 3.2 and pragmatic importance-based approaches in Section 3.3. We introduce the first attempt at utilizing the Fuzzy Best-Worst Method to obtain prioritization weights for barriers identified for CE transition in the FSC.

3.1. Challenges Identification and Categorization

In the first phase of the research objectives, the challenges for adopting CE into the overall FSC need to be identified and effectively categorized such that the proceeding analysis will provide accurate conclusions.

3.1.1. Challenges Identification

The current CE barrier studies are limited to a specific stage of FSC which requires the present study to develop a comprehensive list of challenges that opposes the adoption of CE into the entire FSC. To overcome the evident literature gap in the field [40,41], we utilize SLR to derive a comprehensive list of challenges considering the overall FSC on CE transition.

SLR is an evidence-based approach that condenses and produces a thorough insight into past academic literature, recognizing the gaps, and recommending new research arenas for future studies [42,43]. Unlike traditional reviews, this is a replicable, transparent, and scientific process that reduces selection bias through a literature-wide assessment [43].

We adopted the content analysis-based literature review method of Seuring and Gold [44] to effectively recognize the literature pertaining to barriers to adopting CE and be relevant to the food industry. The exercise of SLR is carried out in three phases: material collection, material selection and evaluation, and challenges identification.

I. Material collection

This selects the relevant keywords, develops search strings, and identifies databases to perform database searches. An in-depth discussion was held among the authors to identify the most relevant keywords that address the objectives of the research. Moreover, certain specific search terms were extracted through the trial-and-error method and inspected the reduced literature pool individually to ensure that all applicable studies are captured.

The defined keywords are used to construct the search string using Boolean Logic. Truncated terms (* sign) are used to expand the range of possible published studies as suggested by Gimenez and Tachizawa [45]. The search string was continuously refined to include all possible keyword combinations. The finalize Boolean search is as follows:

((barrier* OR challenge* OR obstacle*) AND (circular* OR "green supply chain" OR "sustainable supply chain" OR "closed-loop") AND ("food chain" OR "food supply chain" OR "food system" OR "food industry"))

Next, a well-known publisher database, Scopus was selected to ensure the quality and reliability of the work. The finalized keywords string was applied in the search field "Article Title, Abstract, Keywords" of Scopus. No chronic limitation is exercised. The search queries were performed in September 2021 and obtained 196 papers from the Scopus search engine.

II. Material selection and evaluation

After the materials collection is concluded, a series of inclusion/exclusion criteria are applied to screen and select the papers that are relevant to the scope of the study. We first screen the pool of 196 papers based on two criteria: (1) the language in which the articles are written and (2) the quality of the articles based on the satisfactory impact factor of their publication sources.

Since English is the most recognized language for academic publication, we excluded the articles written in non-English languages from the paper pool. Following the standard practice in systematic reviews [46,47], we rejected books, book chapters, theses, conference proceedings, and other types of contributions, and only the articles that are published in peer-reviewed journals were considered quality materials. This process reduced the overall pool of papers to 157.

Next, we performed a manual screening of abstracts based on a defined set of inclusion/exclusion criteria. Using VOSviewer version 1.6.18 for the 157 filtered articles, we carried out a keyword co-occurrence analysis that identified the excluded study topics by evaluating and displaying the relationships between the keywords [48]. The co-occurrences indicate the rate at which the keyword pairings have occurred in the given paper set. The keywords of the paper set are obtained from Scopus and were pre-processed before the analysis. Words that are in structured abstracts referring to methodological aspects (e.g., article, priority journals, analysis, experiment/s) were eliminated and synonyms implying the same denotation yet appeared in various formats were replaced using a thesaurus file to keep the consistency. For example, LCA, life cycle analysis, and life cycle assessment are replaced with life cycle assessment. Figure 1 illustrates the visualization of keyword co-occurrence analysis obtained from the filtered 157 literature pool.

Based on the results, the following inclusion/exclusion criteria can be defined for abstract screening.

Inclusion criteria:

- Conceptual studies based on CE and FSC
- Conceptual studies that focus on CE transition in any FSC and identified challenges for CE adoption

Exclusion criteria:

- Studies focused on water treatment i.e., freshwater, mineral water, wastewater, and sludge-related studies
- Empirical studies on CE-related developments in chemistry, biology, and biotechnology focus on nutritional and laboratory experiments in the food sector, and do not synchronize with research objectives

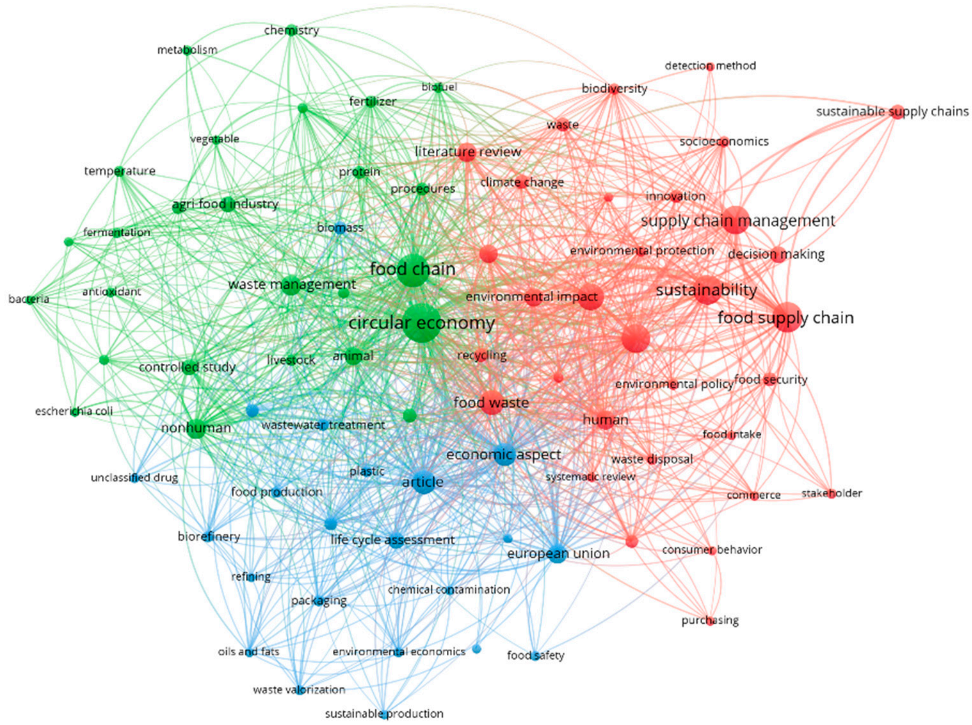

Figure 1. Keywords co-occurrence analysis of 157 papers.

Using the above criteria, the paper pool was reduced to 37 by manually inspecting the titles, abstracts, and keywords for their relevance to the focus areas of our research. For a fair screening process, the introductions and conclusions of some papers were also screened based on the above criteria to finalize the 'review sample'.

Finally, the references in the selected papers were cross-examined to eliminate possible database search limitations and to discover significant proceedings in the research domain. This uncovered 3 papers that did not capture in the initial search that was missed as the search process did not identify their inconsistent keyword usage of them. Adding those 3 papers manually, brought the literature pool into 40 papers that are known as 'review sample'. The overall screening steps are presented in Figure 2. It includes each step of SLR along with the paper count adopting the systematic search process followed by Perera et al. [47].

Figure 2. Systematic process and steps of SLR.

III. Challenges identification

The final phase of the review analysis consists of the collection of data related to the finalized literature pool of 40 papers and summarized results. Full texts of the 40 papers were obtained and the authors read through the papers to distinguish the barriers to adopting CE in sustainable FSCs. While identifying challenging factors, the related information was summarized to construct a rigorous comprehension of the barriers. This content analysis provides extensive insight into the knowledge contributed by scholars [49].

3.1.2. Challenges Categorization

The identified barriers are then categorized into groups that contain similar implications for the supply chains [10]. Challenges categorization is beneficial for prioritization purposes as tables with challenging factors would be less complicated and easily conveyed to the resource persons. Additionally, the results would be clearer and more usable [50,51]. Following the underlying rationale of the classifications suggested by Moktadir et al. [52] for the textile industry and Tura et al. [16] for CE transition in businesses, this work adopted a categorization that has six sections: economic, social, institutional, technological and informational, supply chain, and organizational.

In the second and third phases of the research objectives, the categorized challenges to adopting CE in FSC should be ranked based on a prioritization index. In this paper, we mainly look at two barrier prioritization aspects, considering the literature perspective and the pragmatic perspective.

3.2. Challenges Prioritization—Literature Importance

First, we developed the prioritization of identified challenging factors based on literature importance that built upon SLR. This computes the literature importance for all the challenging factors sequenced generally by the rate of literature occurrence for each factor in a selected literature pool [53–55]. As a fundamental tool for frequency analysis in literature, SLR could be used to measure the occurrence frequency of each factor as it is condensed within the boundary of the study [56]. This aligns with our study approach as the review sample selection was performed based on SLR.

Generally, the ranking is computed for each factor based on the appearance frequency of the factor in the literature pool. However, this is not effective as it can cause possible misestimations for the barrier ranking weights. As a remedy, the frequency analysis is often complemented with a research citation metric-based approach [53]. Among the different types of citation metrics available, article-level citation metrics are more fitting as they appraise citation impact based on the discipline of study and period of publication [57]. This quantifies the impact of published research work historically at the journal level. Between the two article-level citation metrics, Field-Weighted Citation Impact (FWCI) and Relative Citation Ratio (RCR), FWCI is conceded to be the most stable metric for engineering and supply chain research scopes [58]. Thus, we adopted FWCI as the article-level research citation metric to compute the ranking weights and eliminate the misestimation that may be present in a mere literature occurrence analysis.

FWCI indicates the mean citation impact of the literature paper, and it collates the actual citations obtained by the paper with the anticipated number of citations for a paper published of the same kind. It accounts for the document type, publication year, and discipline of the original literature to normalize how well the original paper is cited compared to similar documents. The ratio of the particular article's citations to the average number of citations received by all similar documents over three years is calculated as FWCI [59]. In FWCI, each discipline contributes to the metric equally eliminating the differences in research citation behavior which did not address in traditional metrics.

Correspondingly, the FWCI of the review sample was retrieved from Scopus in the last week of February 2022 to utilize the recent FWCI of the research articles. The prioritization weight of challenging factors is computed employing the frequency of literature appearance and FWCI as per the following Equation:

$$\mathrm{WC_x} = \frac{\sum_{n=1}^{40} \left(\mathrm{i_n} \times \mathrm{FWCI_n} \right)}{40} \quad \begin{array}{l} \mathrm{i_n} = 1 \text{ if } \mathrm{x} \in \text{paper n} \\ \mathrm{i_n} = 0 \text{ if } \mathrm{x} \notin \text{paper n} \end{array} \tag{1}$$

where WC_x is the prioritization weight of a challenging factor x, n is the index of papers in the review sample where $n = 1$ to 40 and $FWCI_n$ is the field-weighted citation impact of the corresponding paper, n. Based on Equation (1), the barrier prioritization based on literature importance is derived.

3.3. Challenges Prioritization—Pragmatic Importance

As the second prioritization approach, we derive the prioritization based on the experiences of professionals with considerable exposure to the FSC. The study first considered the feasible methodologies to analyze the people-centric decisions on CE adoption barriers while bridging a literature gap in the same context.

Our study on CE transition for the FSC considers multiple objectives, alternatives, and criteria. Thus, Multi-Criteria Decision Making (MCDM) methods take dominance in analyzing the professional responses and prioritizing the decisions for our study. Similar studies that use MCDM methods utilize ISM ANP [39], Fuzzy DEMATEL [10,17], Gray DEMATEL [38], and ISM Fuzzy-DEMATEL [60]. These studies, however, are restricted to a single country. Most human decisions-based studies employ uncertainty models such as Fuzzy logic, grey set theory, probability statistics, and rough sets [61,62].

The pragmatic perspective in our study requires ranking real-world challenging factors by involving fuzziness, uncertainty, and complexity of decision-making environments. The uncertainty theories involve input data for the study's empirical aspect, which is usually collected using questionnaires based on experts' experiences in the FSC. As the input data reflects cognitive responses and the membership function is well defined, the grey set theory that handles inadequate information can be excluded [63]. The probability theory can be disbarred as well as the input data need not be from a known distribution derived based on a large sample of historical records [64]. Since the available information is cognitive and a small sample and membership function is well-defined, fuzzy logic is ideal for the analysis [64,65].

Once the uncertainty theory is finalized, a satisfactory MCDM technique needs to be confirmed. Ansari and Kant [66] declared that Analytic Hierarchy Process (AHP) and Data Envelopment Analysis (DEA) are the highest used MCDM techniques in CE and sustainable supply chain management studies. Interpretive Structural Modeling (ISM), Techniques for Order Preference by Similar to Ideal Solution (TOPSIS), Analytic Network Process (ANP), and Decision-Making Trial and Evaluation Laboratory (DEMATEL) are some of the MCDM methods used in similar barrier studies. Further, Best-Worst Method (BWM) is the latest MCDM method proposed by Rezaei in 2015 and there is a lack of studies that employed BWM in analyses until the present [20]. To select an appropriate MCDM technique to combine with fuzzy logic, a comparison between conventional techniques is illustrated in Table 2.

Table 2. Comparison between MCDM techniques used in similar studies.

	DEMATEL	ISM	ANP	AHP	TOPSIS	BWM
Result of the method	Contextual interactions among variables	Causal interactions among variables	Interdependencies among variables	Hierarchical structure of variables	Geometric distance of alternatives	Prioritization and ranking of variables
No. of pairwise comparisons	High	High	High	High	High	Low

BWM is ideal to attain more consistent results, especially when the list of barriers identified is long. Further, it aligns with the research objectives of challenges ranking and employs fewer pairwise comparisons that make the analysis easy. Therefore, BWM combined with fuzzy logic is adopted in the study as the pragmatic survey data analysis method.

3.3.1. Fuzzy Best-Worst Method (FBWM)

To obtain consistent and precise results, Guo and Zhao [20] developed a mathematical model integrating fuzzy set theory and BWM that normalizes the subjectivity of human decisions by incorporating a fuzzy linguistic scale while BWM prioritizes the criteria and alternatives. However, FBWM is rarely exploited in prioritizing barrier factors of adopting CE in an overall FSC. Thus, our proposal of using FBWM to compute the prioritizing weights of challenging factors to adopt CE in the FSC on experiential data contributes to bridging the research inadequacy in the domain. FBWM guided the following steps in the study:

Step 1: Define the list of barriers as the decision criteria as $\{B_1, B_2, B_3, \ldots, B_n\}$.
Step 2: Determine the most important (B_B) and least important barrier (B_W) based on the professional opinion without any comparisons.
Step 3: Using the linguistic scale (see Table 3), the expert was asked to decide the degree of importance of B_B compared to other barriers. A fuzzy reference comparison of the best-to-others vector can be given as $A_B = (a_{B1}, a_{B2}, a_{B3}, \ldots, a_{Bn})$, where a_{Bj} represents the fuzzy importance of barrier B_B over the barrier B_j. Here a_{BB} equals (1, 1, 1).

Table 3. The linguistic scale for decision-makers assessment [20].

Linguistic Terms	Membership Function
Equal Importance (EI)	(1, 1, 1)
Weakly Important (WI)	(2/3, 1, 3/2)
Fairly Important (WI)	(3/2, 2, 5/2)
Very Important (WI)	(5/2, 3, 7/2)
Absolutely Important (WI)	(7/2, 4, 9/2)

Step 4: Utilizing the linguistic scale, the expert was asked to decide the degree of importance of other barriers compared to BW. A fuzzy reference comparison of the worst-to-others vector can be given as $Aw = (a_{1W}, a_{2W}, a_{3W}, \ldots, a_{nW})$, where a_{jW} represents the fuzzy importance of the particular barrier B_j over B_W. Here a_{WW} equals (1, 1, 1).
Step 5: Calculate the optimal fuzzy weights $(w_1^*, w_2^*, w_3^*, \ldots, w_n^*)$

To generate the optimal weights of the challenging factors, for each pair of w_B/w_j and w_j/w_W, there are $w_B/w_j = a_{Bj}$ and $w_j/w_W = a_{jW}$. As a result, it is needed to find a solution where the maximum absolute differences, $\left|\left(w_B/\ w_j\right) - a_{Bj}\right|$ and $\left|\left(w_j/w_B\right) - a_{Bj}\right|$ are minimized. It is to be noted that w_B; w_j; and w_W are TFNs. Thus, the fuzzy weights of barriers represented by TFN $\widetilde{w}_j = \left(l_j^w,\ m_j^w, u_j^w\right)$ needs to be converted to a crisp value. To calculate the relative weights, the below demonstrated constrained optimization needs to be solved.

$$min\ max_j\left\{\left|\frac{\widetilde{w}_B}{\widetilde{w}_j} - \widetilde{a}_{Bj}\right|, \left|\frac{\widetilde{w}_j}{\widetilde{w}_W} - \widetilde{a}_{jW}\right|\right\}$$
$$s.t\begin{cases}\sum_{j=1}^{n} R\left(\widetilde{w}_j\right) = 1\\ l_j^w \leq\ m_j^w \leq\ u_j^w\\ l_j^w \geq 0\\ j = 1,\ 2,\ 3,\ \ldots,\ n\end{cases} \tag{2}$$

where $\widetilde{w}_B = (l_B^w,\ m_B^w, u_B^w)$, $\widetilde{w}_j = \left(l_j^w,\ m_j^w, u_j^w\right)$, $\widetilde{w}_W = (l_W^w,\ m_W^w, u_W^w)$, $\widetilde{w}_{Bj} = (l_{Bj}^w,\ m_{Bj}^w, u_{Bj}^w)$, $\widetilde{w}_{jW} = (l_{jW}^w,\ m_{jW}^w, u_{jW}^w)$

To solve the problem, Equation (2) can be transferred into a nonlinear programming problem as follows:

$$\text{Min } \widetilde{\xi},$$
$$s.t \begin{cases} \left| \frac{\widetilde{w}_B}{\widetilde{w}_j} - \widetilde{a}_{Bj} \right| \leq \widetilde{\xi} \\ \left| \frac{\widetilde{w}_j}{\widetilde{w}_W} - \widetilde{a}_{jW} \right| \leq \widetilde{\xi} \\ \sum_{j=1}^{n} R(\widetilde{w}_j) = 1 \\ l_j^w \leq m_j^w \leq u_j^w \\ l_j^w \geq 0 \\ j = 1, 2, 3, \ldots, n \end{cases} \tag{3}$$

where $\widetilde{\xi} = \left(l^{\widetilde{\xi}}, m^{\widetilde{\xi}}, u^{\widetilde{\xi}}\right)$.

Let $\widetilde{\xi}^* = (k^*, k^*, k^*)$, $k^* \leq l^* \leq m^* \leq u^*$, then Equation (3) can be rephrased as min $\widetilde{\xi}^*$:

$$s.t \begin{cases} \left| \frac{l_B^w,\ m_B^w,\ u_B^w}{l_j^w,\ m_j^w,\ u_j^w} - l_{Bj},\ m_{Bj},\ u_{Bj} \right| \leq (k^*, k^*, k^*) \\ \left| \frac{l_j^w,\ m_j^w,\ u_j^w}{l_W^w,\ m_W^w,\ u_W^w} - l_{jB},\ m_{jB},\ u_{jB} \right| \leq (k^*, k^*, k^*) \\ \sum_{j=1}^{n} R(\widetilde{w}_j) = 1 \\ l_j^w \leq m_j^w \leq u_j^w \\ l_j^w \geq 0 \\ j = 1, 2, 3, \ldots, n \end{cases} \tag{4}$$

Once the $w_1^*, w_2^*, w_3^*, \ldots, w_n^*$ are calculated, those need to be defuzzied as follows:

$$w_d^* = \frac{l_{j^*}^w,\ 4m_{j^*}^w,\ u_{j^*}^w}{6} \tag{5}$$

where w_d^* is the defuzzied value of the importance weight of the particular barrier.

Step 6: Once the importance weights are calculated, the accept/reject decision is calculated using the Consistency Ratio (CR) as in Equation (6). Table 4 provides the Consistency Index (CI) correlated with each linguistic term as per the expert's response. It indicates to which extent BB is more important than B_W displayed as a_{BW}.

Table 4. CI for linguistic terms.

Linguistic Term	EI	WI	FI	VI	AI
$\mathbf{a_{BW}}$	(1, 1, 1)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(7/2, 3, 9/2)
CI	3.00	3.80	5.29	6.69	8.04

$$CR = \frac{\widetilde{\xi}^*}{CI} \tag{6}$$

If CR < 0.10, then the response is considered consistent; otherwise, the respondent is asked to revisit the questionnaire under the guidelines of Guo and Zhao [20].

Step 7: The final weight of the challenging factor is computed by aggregating all the responses from experts as per Equation (7).

$$W_{agg_j} = \frac{1}{K} \times [W_{a_1} + W_{a_2} + W_{a_3} + \cdots + W_{a_K}],\ \mathrm{j} = 1,\ 2,\ 3,\ \ldots,\ \mathrm{n} \tag{7}$$

where W_{agg_j} is the aggregated weight of the particular barrier, W_{a_i} is the defuzzied value of the particular barrier and K is the number of experts who responded to the pragmatic survey.

3.3.2. Data Collection

The questionnaire to collect responses from professionals in the food industry is designed to be aligned with FBWM which only requires responses from a limited number of responses [67]. Therefore, this study collected responses from 21 experts [68,69] who have more than 5 years of experience in the food industry. The sample contains 43% of professionals from the food industry and 57% from academia.

The present study can be applied in any geographical or demographical context as it explored challenging factors of CE transition in the FSC through SLR. On top of that, the empirical survey incorporated experts from several countries with substantial years of experience and exposure in the food sector. Therefore, the study can be nominated as a study with fewer limitations as it conducted exhaustive literature scrutiny while embedding literature importance prioritization and extended to a pragmatic analysis of the barriers.

4. Research Findings and Discussion

4.1. Results of Systematic Literature Review

This section discusses the outcome of the descriptive analysis that was done on the SLR's final pool of 40 articles in its chronical, geographical, and scientific distribution.

4.1.1. Descriptive analysis of Systematic Literature Review

I. Distribution of articles by the year of publication

We analyzed the extracted review sample (see Figure 3) to investigate the research interest of the scholars regarding CE adoption in food system and its trends. Even though in the early years from 2008 to 2015 there has not been any significant research outcome, there is a substantial growth in the number of publications after 2016. This sudden growth can be assumed due to the EU's recent attention to transforming the economy into a much more resilient, eco-friendly, and profit-oriented circular structure introduced in 2014 [70,71]. Therefore, it has been widely brought to the attention of scholars to identify the rationale behind the reluctance to adopt CE in value chains and evaluate CE practices in FSC.

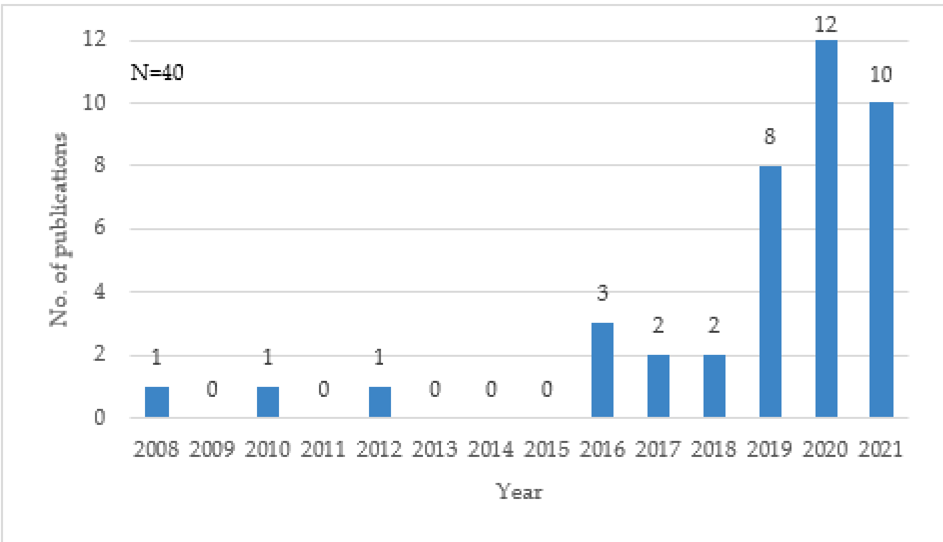

Figure 3. Publication trend of literature pool.

II. Geographical distribution of the pool of literature

We extracted the author's affiliations from the review samples to identify the geographical distribution of the literature which is shown in Figure 4. It illustrates that there is a significant contribution from the EU countries such as the United Kingdom, Italy, and Finland mainly due to the interest of the EU regarding CE adoption in FSC. Research proceedings from UK and Italy indicate the key stakeholder and policymaker alignment toward CE adoption [72,73] due to its high popularity in CE adoption literature. India and China have also shown a great interest in identifying and assessing barriers to adopting CE in FSC even though they have underlying constraints for CE adoption [74].

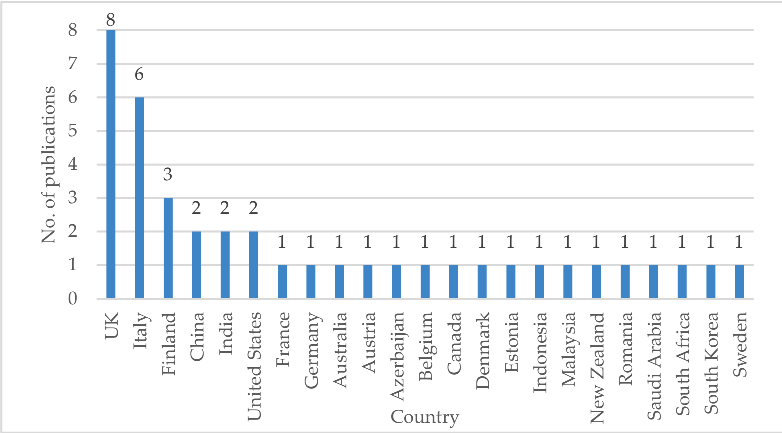

Figure 4. Country-wise distribution of publications.

Considering the regional-wise distribution, it can be seen that 62.5% contribution is from the Europe region mainly due to the EU's CE agenda on food security [2]. The second most contribution is from the Asian region which accounts for 22.5% and it indicates the shift of interest towards CE especially in China as opposed to its restrictions on their internal components and dominance in the linear economy in the supply chain [17].

III. Journal contribution toward literature scope

To determine the journal contribution, we gathered scientific journals that have an impact factor of more than 3 according to the Thomson Reuters Journal Citation Report [75] as they are considered to be good sources in their respective discipline. 32.5% of articles are published in four journals and the rest of the journals that contain only one article are categorized as 'Others'. The interest in CE sustainability and its environmental aspects can be seen by the high number of articles published in the journals of Sustainability Switzerland, Business Strategy and The Environment, Journal of Cleaner Production, and Resources Conservation and Recycling.

4.1.2. Content Analysis of Systematics Literature Review

In an attempt to discover distinct challenging factors that impede CE in FSC, we carried out a thorough analysis of the finalized article pool. Although there are different types of challenges that are pertaining to different stages of the supply chain, those can be identified under similar themes [10] and can be narrowed down to 17 challenging factors. Also, the use of recent publications for the SLR safeguards the applicability of these challenges in modern-day supply chains.

We defined 6 sections to categorize the 17 challenging factors according to the barrier categorization methodologies proposed by Moktadir et al. [52] and Tura et al. [16]. Table 5 showcase the summarized version of the challenging factors with their respective categories.

Table 5. Summary of the extensive list of challenging factors identified through the SLR [76].

Category	Ref.	Challenging Factor	Description
Economic	A1	Cost efficiency considerations	Low economies of scale in the food sorting and recycling operations; expensive recycling materials; high production costs in green agriculture; high logistics costs associated with waste collection and storage for quality preservation prior to reuse; expensive CE processing research and development.
	A2	Issues in investments—scalability and replicability	Assessment of the viability of technologies that are currently available to support the transformation of food waste requires significant investments; the return on investments cannot be predicted before implementation; lack of financial capability; the benefits of CE are difficult to measure and replicate; less willingness in CE investments due to the low ROI.
Social	B1	No trade and social pressure	Lack of trade pressure and price competitiveness for CE-related food products due to a lack of players in the industry; low reaction to demand from local and global markets; promotion of the green side is slow or poor in some projects.
	B2	Lack of societal acceptance and demand	Limited knowledge of the advantages of CE-related food items and services in terms of the environment and the economy; uncertainty about the quality of the products and doubts on health concerns associated with CE practices; the commercial strategies implemented by CE have not yet fully satiated consumers' cultural, social, and psychological requirements.
Institutional	C1	Less enforcement of legislation and regulations	Lack of penalties for policy violations; ineffective administrative processes that impede CE business models; absence of single-use plastic food packaging bans; absence of food quality control and criteria; absence of standards and policies that promote CE initiations; complex government structure and policy framework; misinterpretation of policies.
	C2	Insufficient subsidies and uncertainty of incentives	Governments do not subsidize where incentives are uncertain; lack of subsidies that fund the research gaps in CE; lack of subsidies and tax treatments for CE products and business models; inaccessibility for grant funding; even subsidizing farmers does not lead to the use of innovative technologies that promote resource efficiency and CE.
Technological and Informational	D1	Lack of information on sustainable processes; less transparency	Lack of production and cost data limits LCA assessments; a lack of knowledge about the material used in production restricts recycling because mixed materials cannot be recycled; challenges in gaining access to data from multiple FSC actors; a lack of a reliable method to estimate food waste; a lack of knowledge about food processing; complexity in LCA accounting.
	D2	Lack of awareness and expertise	Less professional knowledge and skills needed for CE implementation and lack of training; limited environmental awareness; less knowledge of quality standards and safe handling; less awareness of the value of trash.
	D3	Technological difficulties and R&D deficiency	Lack of technical readiness in FSC and laboratories; difficulties determining the quality and hygienic standards of CE-related items; inefficient use of technology for labor-intensive tasks, such as sorting plastic waste.
	D4	Problems in innovations	Some CE methods take a lot of energy; are not very user-friendly; lack quality in circular products; have few innovations.
Supply chain	E1	Geographical challenges	Between food waste collection and CE transformation hubs, there are storage and transportation issues; there is also less transparency and tracking.
	E2	No long-term shared vision among stakeholders	Intellectual property and firm confidentiality issues; the complex ecosystem and viewpoints among FSC actors; market competitiveness and brand image; a lack of network and system support; gaps in extended producer responsibility; low industry practitioner and academic collaboration.
	E3	Competition from existing linear businesses	Overly reliant on lands hinders agricultural innovation; high investment costs for CE as fossil fuel prices are low; price volatility favors importing food over growing it; CE is deterred by linear firms' high ROI.
	E4	Lack of support from the logistics network and reverse logistics management	Lack of supply chain design and optimization; high vulnerability to FSC disruptions, such as natural disasters; lack of quality packaging and cold chain that retain food for a long time; outdated organizational mechanisms; either a lack of quality measures or high-quality standards within the food chain; difficulties managing circular FSC due to its complexity.

Table 5. *Cont.*

Category	Ref.	Challenging Factor	Description
Organizational	F1	Lack of infrastructure and methodologies	Outdated warehouse and transportation systems; problems with the separation of food and packaging waste; lack of information tools for FSC management; processing inefficiencies; inaccurate product projections result a high volume of waste production.
	F2	Top management reluctancy	Lack of organizational preparation; poor leadership; unfavorable economic assessment prevents the deployment of CE.
	F3	Employee connectedness and company culture	Due to a lack of time, poor vision, and limited resources, businesses lack CE understanding, practices, and teamwork; FSC lacks CE indicators; employment of green financial policy inefficiently.

4.2. Results of Challenges Prioritization—Literature Importance

We ranked the challenging factors based on their importance according to the methodology elaborated in Section 3.2 using the frequency analysis of barriers. In order to tackle the limitation of the frequency analysis [56], we utilized FWCI as an article-level research citation metric. FWCI of articles in the literature pool on the last week of February 2022 is obtained for the analysis. The frequency of literature occurrence of challenging factors is attached in Appendix A. The prioritization weights of challenging factors derived according to the literature importance using the frequency analysis combined with FWCI are shown in Table 6.

It can be observed that the cost efficiency considerations (A1 "2.96") have the highest weight implying the most important barrier followed by the less enforcement of legislation and regulations (C1 "2.29") and no long-term shared vision among stakeholders (E2 "1.94"). These rankings should be considered when addressing and eliminating the respective barriers [17]. However, the rankings will differ if we use a category-wise literature importance ranking as opposed to ranked challenging factors. However, the importance of ranking based on challenging factors will remain high [10] as these are considered individually.

Table 6. Results of literature importance prioritization.

Category	Ref	Challenging Factor	Weights of Challenges	Ranking
Economic	A1	Cost efficiency considerations	2.96	1
	A2	Issues in investments—scalability and replicability	0.82	12
Social	B1	No trade and social pressure	0.64	15
	B2	Lack of societal acceptance and demand	1.69	6
Institutional	C1	Less enforcement of legislation and regulations	2.29	2
	C2	Insufficient subsidies and uncertainty of incentives	1.37	8
Technological and Informational	D1	Lack of information on sustainable processes; less transparency	1.91	4
	D2	Lack of awareness and expertise	1.67	7
	D3	Technological difficulties and R&D deficiency	1.74	5
	D4	Problems in innovations	0.43	17
Supply chain	E1	Geographical challenges	0.99	11
	E2	No long-term shared vision among stakeholders	1.94	3
	E3	Competition from existing linear businesses	1.17	10
	E4	Lack of support from the logistics network and reverse logistics management	0.78	13
Organizational	F1	Lack of infrastructure and methodologies	1.29	9
	F2	Top management reluctancy	0.69	14
	F3	Employee connectedness and company culture	0.44	16

4.3. Results of Challenges Prioritization—Pragmatic Importance

As the third objective of the study, we prioritized challenging factors based on empirical data. According to the methodology in Section 3.3, their responses were used to complete the comparison matrices based on the linguistic scale in Table 3. Then we attained the defuzzied weights of challenging factors using Equation (5) via obtaining the optimal barrier categories and barriers based on FBWM introduced by Guo & Zhao [20]. This resulted in a non-linear minimization problem of which the global optimization could be achieved with Lingo software [68]. We used Lingo 18.0 version to derive optimal TFN values and the objective functions. Tables 7 and 8 display the FBWM results for barrier categories and challenging factors respectively. We have attached one of the expert responses with the simplified non-linear programming equations for the ease of understanding the aggregation of FBWM results for readers.

Table 7. FBWM results for barrier categories.

Barrier Category	Fuzzification			Defuzzification	Rank
	l	m	u		
Economic	0.1834	0.2099	0.2269	0.2083	1
Social	0.1274	0.1393	0.1552	0.1400	5
Institutional	0.1252	0.1252	0.1606	0.1311	6
Technological and Informational	0.1509	0.1738	0.1927	0.1732	3
Supply Chain	0.1617	0.1850	0.2107	0.1854	2
Organizational	0.1326	0.1479	0.1621	0.1477	4
$\widetilde{\xi}^*$					0.6591
CR					0.0874

Table 8. FBWM results and optimal weights of challenging factors.

Category	Category Weights	$\widetilde{\xi}^*$	CR	Barrier Ref.	Fuzzification			Local Weights (Defuzzification)	Global Weights	Ranking
					l	m	u			
Economic	0.2083	4.4×10^{-8}	5.5×10^{-9}	A1	0.7675	0.7889	0.8744	0.7996	0.1666	1
				A2	0.1943	0.1972	0.2193	0.2004	0.0417	13
Social	0.1400	6.5×10^{-8}	8.1×10^{-9}	B1	0.4796	0.4796	0.5772	0.4959	0.0472	11
				B2	0.3867	0.4796	0.7194	0.5041	0.0928	2
Institutional	0.1454	6.6×10^{-8}	8.2×10^{-9}	C1	0.5736	0.5845	0.6675	0.5965	0.0782	3
				C2	0.3781	0.3937	0.4680	0.4035	0.0529	8
Technological and Informational	0.1732	5.5×10^{-1}	7.9×10^{-2}	D1	0.3405	0.3405	0.3936	0.3494	0.0605	4
				D2	0.1718	0.1901	0.2637	0.1993	0.0345	15
				D3	0.3256	0.3405	0.3635	0.3419	0.0592	5
				D4	0.1061	0.1061	0.1257	0.1094	0.0189	17
Supply Chain	0.1854	4.6×10^{-1}	7.0×10^{-2}	E1	0.1491	0.1703	0.1963	0.1711	0.0317	16
				E2	0.2819	0.3073	0.3351	0.3077	0.0571	6
				E3	0.2401	0.2668	0.2966	0.2674	0.0496	10
				E4	0.2278	0.2521	0.2867	0.2538	0.0471	12
Organizational	0.1477	4.1×10^{-1}	6.0×10^{-2}	F1	0.3185	0.3563	0.4023	0.3577	0.0528	9
				F2	0.3257	0.3578	0.4098	0.3611	0.0533	7
				F3	0.2546	0.2781	0.3202	0.2812	0.0415	14

We can observe that the economic category is the most important barrier followed by the supply chain and technological and informational categories as per the experts in the food industry. The institutional category is the least focused barrier in the eyes of the experts with a pragmatic background in the said industry since government and policy-making institutes are beyond the industry boundaries.

Before deriving the final CR, responses that exceeded CR of more than 0.1 were redistributed to relevant experts to reevaluate, and then it was taken into account which ensures the results are consistent and accurate. Furthermore, our results resonated with similar studies that were performed in different sectors of FSC [77].

As the defuzzied weights are local, we needed global weight factors (Equation (8)) to compare challenging factors among different categories.

$$\text{Global weight of the barrier} = \text{Local weight of barrier (Defuzzification of barrier)} \times \text{Weight of the respective barrier category} \quad (8)$$

Table 8 displays the calculated global weight factors and rankings. We obtained the rankings by aligning with the barrier category prioritization, where the most crucial barrier is cost efficiency considerations (A1 "0.1666") in the economic category.

4.4. Comparison of Barrier Prioritization—Literature vs. Pragmatic Ranking

As the final objective, we have compared the two prioritizations, which were the literature importance of challenging factors deduced by the SLR and the pragmatic importance of the barriers based on the responses from industry experts in the food supply chain. In the final phase, we are evaluating the similarities and differences in theoretical and empirical perspectives towards CE adoption barriers in the food industry.

When we compare the barrier ranking of both literature and empirical importance as shown in Table 9, it was observed that cost efficiency considerations (A1) were the most important factor in both prioritizations which leads to the fact that the literature findings are verified by the industry experts. This was stated in the earlier works of Dossa et al. [35] and Gedam et al. [10]. Most of the rankings are similar or deviated slightly in the two prioritization methods ensuring that there is a high correlation of rankings between the contrasting barriers. There are only two factors that deviated significantly, and they are namely, lack of awareness and expertise (D2) and top management reluctance (F2). These occasional deviations are mainly due to the differences in dependencies with category weights and barrier weights in the ranking calculation.

Table 9. Comparison of barrier prioritization between literature and pragmatic importance.

Barrier Category	Ref	Challenging Factors	Literature Importance Ranking	Pragmatic Importance Ranking
Economic	A1	Cost efficiency considerations	1	1
	A2	Issues in investments—scalability and replicability	12	13
Social	B1	No trade and social pressure	15	11
	B2	Lack of societal acceptance and demand	6	2
Institutional	C1	Less enforcement of legislation and regulations	2	3
	C2	Insufficient subsidies and uncertainty of incentives	8	8
Technological and Informational	D1	Lack of information on sustainable processes; less transparency	4	4
	D2	Lack of awareness and expertise	7	15
	D3	Technological difficulties and R&D deficiency	5	5
	D4	Problems in innovations	17	17

Table 9. *Cont.*

Barrier Category	Ref	Challenging Factors	Literature Importance Ranking	Pragmatic Importance Ranking
Supply Chain	E1	Geographical challenges	11	16
	E2	No long-term shared vision among stakeholders	3	6
	E3	Competition from existing linear businesses	10	10
	E4	Lack of support from the logistics network and reverse logistics management	13	12
Organizational	F1	Lack of infrastructure and methodologies	9	9
	F2	Top management reluctancy	14	7
	F3	Employee connectedness and company culture	16	14

Even though there are CE-related barrier studies in the food industry; various stages of the food chain or different supply chains, there was no study to be found as our best knowledge of us, which evaluates both literature and empirical data to derive a comparison between two prioritizations. Further, we were able to identify studies [33,38,74,78,79] which align with the results of our work. There are some differences as these studies were carried out on different supply chains not only limiting to the food supply chain. But our work stretches beyond the barriers defined in previous studies by incorporating an extensive list of 17 challenging factors while concluding the cost efficiency considerations (A1) as the most important barrier to mitigate first by both literature and pragmatic importance analysis.

5. Managerial Implications

This paper yields prescient intuition and production predominant theoretical contributions to CE implementation in the food system. The barrier identification, categorization, and prioritizations to thrust the execution of CE in the food chain. This study highlighted the cost efficiency considerations as the most crucial challenging factor for CE transition in the food industry validated by both analyses. CE adoption is a cost-intensive paradigm and organizations in the food industry find it difficult to invest in experimental, costly products or services where the outcome is unrealized [78,80]. Thus, firms need to understand the impact of the FSC in the sustainable arena and strengthen the financial capabilities of circular products and services to gain long-run benefits. Businesses in the food industry are compelled to adopt circularity to address global food security and eliminate hunger that is yet to happen. Therefore, taking extra steps for CE transition is emphasized in this study.

Other than financial considerations, less enforcement of legislations and regulations, lack of long-term shared vision among stakeholders, and lack of societal acceptance are identified as the most impactful challenging factors in food chain adoption of CE. Although EU countries, China, the UK, and the US have taken the forefront by adopting and promoting CE as state and regional policies, most of the world has not paid enough attention to the cruciality and timeliness of CE adoption in the food industry. Even the aforementioned economies faced a lack of enforcement of regulations as the implementation is more controversial than the promulgation, supported by low administrative status and prevailing corruption associated with the extant linear economy [17]. Therefore, the government should actively collaborate with policy-making institutions in this regard to implement more stringent regulations that enforce performance and monitor the practices advised. Education and awareness of CE, formulation of green policies and regulations, and legislation and monitoring can drive CE adoption in the food system. Governmental and bureaucratic support, along with other stakeholders in the value chain is critical for CE transition as a lack of long-term shared vision hinders the process. Businesses should explore government support and subsidies for financing while taking the opportunities of sustainability collaborations, eco-industrial parks, resource valorizations, and eco-innovations [81]. Development of a common strategy that circulates resources among food chains and businesses involved in between would be the initial step of executing collaboration among stakeholders and it will ultimately gain societal acceptance as all businesses connected towards one shared goal. Another critical barrier of lack of societal acceptance can be eliminated accordingly while aligning CE with social beliefs, culture, and awareness.

It would be valuable for decision-makers, policymakers, and managers in the sector to identify the problematic elements in order to determine which areas need immediate attention for the CE transition. As the essential and fundamentals of problematic elements are defined in the study, this work will serve as a reference for designing strategies according to the specific industry in the food system. This study also draws attention to the plethora of opportunities that can be obtained from the CE application, including potential supply chain collaboration and effective reuse and recycling procedures. However, once the most prominent barriers are addressed it is essential to mitigate remaining challenges as they collectively drive the CE transition in sustainable FSCs.

Despite following a robust methodology in the study, there are a few limitations worth noting. Even though we utilized Scopus which is one of the largest peer-reviewed academic literature databases, there might be database limitations and studies that have not been captured in our literature pool. Further, we employed frequency analysis combined with FWCI for literature prioritization of challenging factors and it might be limiting the results as FWCI is updated weekly and with time the identified importance can be altered.

The comparison between literature importance and pragmatic importance alleviates fresh research objectives such as: investigating the consequences of similarities and differences between two rankings; finding a way to bridge the different prioritizations in literature and pragmatic perspectives to implement CE optimally in the food system. Thus, the literature future in CE is infinite and scholars are required to pay diligent attention to circularity frameworks while industries follow the recommendations collaboratively. That will lead to a world free from food trilemma and achieve sustainability.

6. Conclusions

In a nutshell, this study yields significant attention to CE implementation in sustainable FSCs by identifying and prioritizing the barriers that hinder the adoption. This work found 17 challenging factors of CE adoption related to FSC via an SLR. Then the challenges are classified into six barrier categories following the frameworks of previous reviews. The challenging factors were prioritized based on literature importance declared by associate scholars and pragmatic importance defined by professions in the food industry.

Cost efficiency consideration (A1) resulted as the most crucial barrier to be tackled by both prioritizations. Less enforcement of legislation and regulations is ranked as the second most pivotal challenge by literature appearance while experts placed it in third place. Correspondingly, this work highlights the rankings of challenging factors and the necessity of extending interest into such factor rankings, elaborating on the current issues faced by FSC. The adoption of CE principles in prominent economies and the inadequacy of obligatory measures related to FSC are discussed as well.

Further, the comparison of the two rankings provides insight into the contrasting and similar perspectives of academia and practicality. Therefore, this work can be exercised as a handbook for governments, policy, and decision-makers as well as top management of the business to determine the crucial factors to be eliminated initially for effective implementation of CE in the food system and bridge the perception gap of theoretical and empirical interpretations.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Appendix A.1. Final Literature Pool of 40 Papers

1—[82]
2—[83]
3—[34]
4—[9]
5—[84]
6—[21]
7—[85]
8—[22]
9—[86]
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31—[46]
32—[100]
33—[40]
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35—[41]
36—[72]
37—[102]
38—[10]
39—[103]
40—[104]

Appendix A.2. Frequency of Literature Occurrence of Challenging Factors

Table A1. Frequency of challenging factors occurrence in review sample.

Year	2008	2010	2012	2016	2016	2016	2017	2017	2018	2018	2019	2019	2019	2019	2019	2019	2019	2019	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2021	2021	2021	2021	2021	2021	2021	2021	2021	2021	#[1]
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	
A1	✓	✓	✓					✓	✓			✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	29
A2							✓				✓									✓	✓				✓							✓						✓	✓		8
B1			✓		✓				✓				✓						✓											✓	✓										7
B2	✓	✓	✓		✓	✓			✓			✓		✓	✓	✓	✓				✓		✓		✓	✓	✓	✓		✓	✓	✓		✓		✓	✓	✓	✓	✓	26
C1	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓		✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	32
C2	✓				✓	✓									✓		✓		✓		✓			✓	✓	✓	✓	✓		✓	✓	✓			✓	✓				✓	18
D1	✓	✓		✓						✓			✓		✓	✓		✓		✓				✓			✓		✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	21
D2	✓	✓	✓						✓			✓	✓		✓			✓	✓		✓		✓		✓			✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	22
D3	✓					✓			✓				✓			✓		✓	✓		✓	✓	✓		✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	22
D4							✓		✓							✓			✓			✓				✓		✓	✓									✓			9
E1				✓		✓											✓										✓		✓		✓	✓	✓			✓				✓	10
E2	✓	✓			✓	✓			✓	✓	✓	✓	✓			✓		✓	✓		✓				✓			✓	✓	✓		✓				✓	✓	✓	✓	✓	23
E3					✓			✓			✓			✓	✓	✓			✓						✓									✓						✓	10
E4					✓							✓			✓				✓		✓		✓	✓			✓							✓	✓	✓		✓		✓	13
F1	✓			✓	✓								✓				✓	✓	✓	✓		✓	✓		✓	✓				✓			✓	✓	✓	✓	✓		✓	✓	20
F2	✓	✓	✓		✓				✓										✓		✓		✓												✓		✓	✓		✓	12
F3			✓									✓	✓								✓																				4

[1.] Total number of occurrences in the literature.

Number 1 to 40 indicates the articles in the literature pool as per A.1 and reference A1 to F3 indicates the challenging factors as per Table 5.

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