

Implementing circularity in food supply chains: the facilitating role of intermediaries

Viscardi Stella*, Colicchia Claudia*, Creazza Alessandro**

* *Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Via Lambruschini 4/b, 20156 – Milano – Italy* (stella.viscardi@polimi.it, claudia.colicchia@polimi.it)

** *School of Industrial Engineering, LIUC University, Corso Matteotti 22, 21053 – Castellanza – Italy* (acreazza@liuc.it)

Abstract: According to FAO estimates, food waste represents one third of the globally produced food, entailing a considerable waste of resources. Circular economy (CE) principles, which aim at reducing the use of resources and at the elimination of waste flows, have the potential to mitigate the generation of food waste. CE adopts a system perspective, meaning everyone should be involved in the efforts for circularity, and collaborations between companies and sectors are encouraged to extract as much value as possible from waste flows. However, there are several barriers encountered by companies in the shift to circularity. These have been widely explored in the literature, and include the uncertainty about material flows, difficulties in finding the appropriate partners, and the geographical dispersion of companies able to valorize the waste. Overcoming such barriers is paramount to implement CE in food supply chains (SCs). Therefore, this work aims at exploring how an external actor in the form of an intermediary might orchestrate the flows of waste materials to effectively manage the circularity of food SCs and mitigate the obstacles that companies might face. Different types of intermediaries have been presented in the existing literature, such as scavengers, brokers, or facilitators, and these external actors are often engaged in a multitude of activities. By adopting a systematic literature review methodology their description in literature is explored, and the functions of intermediaries are clustered into nine categories, also allowing to understand their peculiar characteristics, roles, and positioning in the SC. Given the numerous barriers faced by food companies, the insights gathered on the existing barriers and on the intermediaries’ functions will be combined to conceptualize how an intermediary might mitigate the obstacles to CE and facilitate the development of circular food SCs.

Keywords: Circular economy, Intermediary, Food waste, Supply chain

I. INTRODUCTION

According to FAO estimates, food waste represents one third of the globally produced food [1]. This significant amount of waste translates into impacts at environmental, social, and economic level: the food wasted every year is responsible for the 8% of the overall amount of greenhouse gas emission [2], accounts for an economic loss of 1 trillion USD [3], and represents a reduction of food availability, so it contributes to food insecurity [2]. Considering all these implications, finding solutions that could mitigate the generation of food waste is of paramount importance.

CE, defined as “an industrial system that is restorative and regenerative by intention and design” [4], has been presented as a promising approach to reduce the generation of waste, since its aim is to close the loop of materials by replacing the end of life with alternative solutions that exploit the residual value of waste flows [2] [4] [5].

The presented definition of CE stresses its holistic perspective, which is particularly suited to address system-wide problems such as food waste. Wastage of food occurs at all the stages of the food SC, from primary production to final consumer [6], so by adopting the

systemic approach of CE, circular SCs can be introduced. According to literature, circular supply chains can have different arrangements: open-loop SCs, where circular flows are created between actors belonging to different SCs, and closed-loop SCs, where the resources are looped within the same SC [7]. To establish these arrangements, companies need to engage with other stakeholders to create circular flows, which might pose obstacles to the development of circular SCs [8].

This paradigm shift requires strong efforts from the involved companies and can be hindered by the presence of several barriers to circularity (see for example [8], [9] or [10a]). The complexity of this transition is also related to the need of creating coordination mechanisms with other stakeholders, either inside or outside the SC, towards a circular supply chain management (CSCM). Recalling the principles of CE, CSCM has been defined as “...the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a

product/service lifecycle including parts/product manufacturers, service providers, consumers, and users.” [10b]. The creation of collaborations among organizations can be facilitated by the presence of an external actor, such as the technology provider [11], or the facilitator in industrial symbiosis projects [12]. The work by Ciulli, Kolk and Boe-Lillegraven (2020), based on social network theory, introduces the construct of a “circularity broker”, which connects actors with materials that have no value to them with other actors that can use those materials, aiming to bring together disconnected parties and create circular material flows [13].

Stemming from these considerations, this study is aimed at exploring the facilitating role an intermediary could have in the development of circular solutions in food SCs, by considering the contextual barriers companies operating in this sector might face when approaching CE. To pursue this objective, a systematic literature review has been carried out, aimed at the identification of different actions carried out by intermediaries, then discussed in relation to the existing barriers to understand how their activities might mitigate challenges faced by companies.

Section II aims at grounding this research in theory and presenting a list of barriers to CE. In the next sections the objective will be better detailed, along with the description of the methodology adopted to pursue the aim of the research. Section V provides an overview on the findings and proposes a categorization of intermediaries’ functions, that are then connected to the identified barriers in section VI. The conclusion delineates some further developments of the research and highlights the contributions and limitations of the current work.

II. THEORETICAL BACKGROUND

The starting point of this research is the recognition of the high complexity associated with the transition to a CE. Given the system-wide nature of CE, companies willing to undertake this paradigm shift are exposed to a multitude of barriers, from institutional settings to internal company culture, to the relationship with SC partners [9]. The classification presented by Tura *et al.* (2019) encompasses environmental, social, institutional, technological and informational, SC, and organizational aspects [9]. This clustering has been adopted to analyse the most common barriers companies might face when trying to implement circular initiatives, since it highlights the complexity of introducing the CE principles in industrial systems, and the multifaceted problems that might emerge. Table I lists barriers derived from different literature contributions, some dealing specifically with food SCs [14] [15] [16], while others more generally discussing industrial contexts [8] [9] [10] [17]. The set of discussed barriers are homogeneous among the analysed contributions, but regarding the food

context one further obstacle to circularity is the short life span of food products [16].

Considering intermediaries, the paper by Ciulli, Kolk and Boe-Lillegraven (2020) well conceptualizes their role in the shift to CE [13]. The work, which builds on social network theory to encompass CE considerations, introduces the concepts of “circularity holes” and of “circularity brokers” [13]. The circularity hole is related to the social network theory concept of “structural hole”, which represents a situation where actors in the network are unevenly connected and unable to share information [18] [19]. The circularity hole introduces the flow of waste materials, which is hindered between actors since its residual value is not recognized by the owner and by the potential receiver [13]. In traditional social network theory, brokers are the actors that can bridge structural holes by facilitating transactions between disconnected actors, located on opposite sides of the hole [20] [21a]. Beyond the creation of new connections between organizations, the broker can also facilitate the coordination and the development of existing relationships [20]. To bridge circularity holes a circularity broker is needed, in charge of connecting actors that have a waste flow that has no value to them with other actors that can extract value from the same waste flow [13]. This activity might also entail the link of parties that are already exchanging other resources but are disconnected regarding waste flows [13].

TABLE I
BARRIERS TO THE IMPLEMENTATION OF CE INITIATIVES (ADAPTED FROM [8] [9] [10] [14] [15] [16] [17])

Economic (E)	Social (S)	Institutional (I)
1 High initial investment and lack of financial capabilities 2 Time mismatch between revenue and cost streams 3 Low prices of virgin raw materials 4 Potential increase in costs	1 Lack of awareness and involvement (in consumers, companies, and suppliers) 2 Failing to meet customers standards with circular products	1 Inadequate and complex existing legislation and policies 2 Lack of incentives and governmental support 3 Lack of appropriate and standard performance assessment system for CE
Technological and Informational (TI)	Supply Chain (SC)	Organizational (O)
1 Lack of adequate technologies, infrastructures, and innovation for CE 2 Lack of information, skills, and knowledge on CE 3 Short life span of food 4 Limited availability of recycling material 5 Difficulties in managing the product quality through the life cycle	1 Lack of network support, collaboration, coordination 2 Lack of information exchange and trust issues 3 Geographical dispersion and limited capacity of reverse logistics 4 Return flows uncertainty 5 Strong focus on linear SC	1 Incompatibility with current linear culture 2 Lack of management support and conflicts with current business culture 3 Fear of risks 4 Limited business model applications

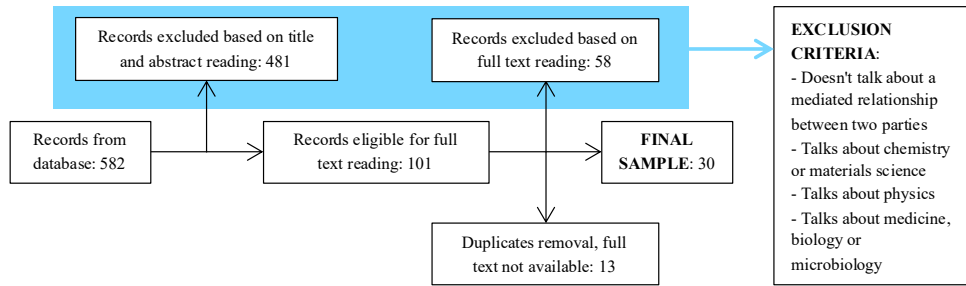


Fig. 1. PRISM diagram of the systematic literature review and exclusion criteria

III. OBJECTIVE

Literature reports several barriers that hinder the development of CE and introducing a third-party actor might represent a valid approach to overcome such challenges. Through the description of circular initiatives that include the presence of an intermediary, the objective of this paper is the exploration of who can play the role of the intermediary, which actions are carried out by such actors, and how they are positioned in the network. Studying these aspects, and the positive influence they might have on the development of CE projects, can help assess and understand how they might mitigate barriers to circularity. This conceptualization can highlight the most relevant functions played by intermediaries, and address the capabilities required to tackle the various and multifaceted challenges faced by companies in the development of circular solutions in food SCs. This study will answer to the following research question: “*What characteristics should an external actor have in order to facilitate the development of circular food SCs?*”.

IV. METHODOLOGY

To answer to the presented research question, a systematic literature review approach has been adopted. An initial snowball sampling has allowed the identification of different actors engaging in intermediating activities, described in literature with the use of different terms. This first analysis has guided the definition of the keywords employed during the search phase, displayed in table II. A total of eight queries has been created, through the combination of each of the keywords about intermediaries with the keyword “circular*”, to embed the research in the CE context. Filters on the subject area and on the language have then been applied to the whole set of strings. The search has been limited to records in English and belonging to one of the following subject areas: economics, econometrics, and finance, agricultural and biological sciences, engineering, social sciences, decision sciences, earth and planetary sciences, business, management, and accounting, environmental sciences, multidisciplinary, undefined.

The described search procedure has been conducted on the database Scopus, that offers a wider journal coverage in the fields of natural sciences and engineering and

social sciences, with respect to Web of Science [21b]. The search on the database has led to the identification of 582 results, which have been screened with the application of exclusion criteria. The criteria aimed at excluding all those results that don’t discuss a CE initiative with the presence of an intermediary, and that treat topics related to chemistry, materials science, physics, medicine, biology, or microbiology. These specifications have been first applied to title and abstract reading, and then to the full-text reading; most of the records have been excluded based on the topic, since were related to chemistry, materials science, physics, medicine, biology, or microbiology. The entire selection process has been conducted in the months of February and March 2022 by two reviewers to remove the subjective judgement about inclusion or exclusion [22a]. The final sample is composed of 30 articles (the papers composing the sample are [13] and from [22b] to [50]); the PRISM diagram in figure 1 summarizes the screening and selection procedure and the applied exclusion criteria.

TABLE II
RESEARCH STRINGS EMPLOYED IN THE SYSTEMATIC SEARCH

#	KW		KW		Subject area
1	Broker*	AND	Circular*	AND LIMIT TO	Economics, econometrics, and finance
2	Intermediar*	AND	Circular*	AND LIMIT TO	Agricultural and biological sciences
3	Matchmaker*	AND	Circular*	AND LIMIT TO	Engineering Social sciences
4	Facilitator*	AND	Circular*	AND LIMIT TO	Decision sciences
5	Scavenger*	AND	Circular*	AND LIMIT TO	Earth and planetary sciences
6	Provider*	AND	Circular*	AND LIMIT TO	Business, management, and accounting
7	Mediator*	AND	Circular*	AND LIMIT TO	Environmental sciences Multidisciplinary
8	Orchestrator*	AND	Circular*	AND LIMIT TO	Undefined

V. FINDINGS

The CE initiatives described in the retrieved papers are operated in several different sectors (such as the food industry, municipal solid waste management, the construction industry, the textile industry...), and countries (The Netherlands, China, Colombia, Sweden, Finland, France...). In these projects, the involved intermediary is defined in multiple ways (transition broker, promotor, intermediary, matchmaker, scavenger...) and is represented by varying actors.

The intermediary can be an organization (private or public-private), an association, a cooperative, a team of researchers, a public institution, a platform, or even a single individual. The multiplicity of actors that can play the role of the intermediary translates into their diverse positionings in the CE network. The simplest distinction is on involvement or not in the circular activities: the intermediary can be an actor whose activities are integral part of the CE project (see for example [22b] or [23]), or that isn't directly involved in the circular operations (see [24], [25]).

Despite the diverse contexts and roles, nine common functions performed by intermediaries have been identified, described here below.

Supply and demand matching (1): this function refers to the ability of the intermediary to find a match between supply and demand of waste flows, to enable the creation of circular flows and create a network and market for these products; it might also entail looking for the right partner. This function is widely discussed in the paper sample. For example, de Jong and Mellquist (2021) presents the case of an online B2B marketplace for plastic waste, where companies willing to use plastic waste as resource in their operations can find the adequate supplier [26]. In the context of industrial symbiosis projects, Patala, Salmi and Bocken (2020), reported on the largest facilitated industrial symbiosis in Finland, Finnish Industrial Symbiosis System [25]. In this network, the intermediary is charge of finding synergies among the participants, so to identify the right partners to match supply and demand [25].

Mediation to foster collaboration (2): the intermediary often acts as mediator between two or more parties and helps develop or strengthen collaborations. This function might be fulfilled by the provision of a space for collaboration (e.g., platforms [13] [27], meetings [28] [29], ...), by helping companies in defining contractual agreements [22] [30], or by performing actions aimed at building trust, by permitting the interaction and engagement between network members [31] [32].

Asset ownership (3): in some cases, the intermediary owns assets, such as trucks or technologies, offered to the network members to operationalize CE actions. In the case of a Chinese project aimed at distributing manure to be used as fertilizer, the cooperative that connects livestock farms and crop farms owns trucks to transport the manure and thus bridge the spatial gap between the

farms [23]. In the case presented by Zerbino *et al.* (2021) of a formal scavenger for paper waste, the assets owned by the intermediary are mobile waste compactors, that not only transport the waste, but also prepare it for recycling through compacting [33].

Knowledge dissemination and communication facilitation (4): this role is commonly performed by the intermediary, who is knowledgeable on CE and can disseminate this expertise (to consumers or to companies) and is in charge of establishing communication channels between parties to facilitate the sharing of information. The intermediary can either be the orchestrator of the information sharing, by keeping contacts with all the stakeholders involved [34] or set up appropriate communication mechanisms between actors to promote the information sharing in the network [30] [35]. Similarly, knowledge about CE practices can be shared with all stakeholders, including consumers, through organized sessions [32] [36] or by simply engaging in the network activities [37] [38].

Initiation and coordination of CE projects (5): the CE project is in some cases conceptualized, initiated, and planned by the intermediary itself. The planning of the project might include the identification of the most appropriate stakeholders to be involved, such as policymakers or technical experts [39] [40] [41] or setting the scope and direction of the project [42] [43]. When the intermediary performs this function, it might also oversee the project management, thus performing activities such as decision making or activities coordination [30] [44].

Flow procurement, preparation, and mobilization (6): the waste flows to be looped can be managed by the intermediary, who might take on one or more of these actions: procurement of materials [29] [33], preparation of the materials [40] [45], and flow movement between supply and demand [46] [47].

Foreseeing and measuring impact of CE (7): among the possible functions, intermediaries could be asked to provide a tangible measure of the benefits, implications, and impacts deriving from circular activities [13] [26], even before the project start [24] [25].

Act as warrantor (8): all the actors involved in circular initiatives have their own interests, so the intermediary could be in charge of acting as neutral warrantor to protect all the involved parties [22] [48]. This same role could be devoted to ensuring the quality of flows in the circular network, both on the waste flows and on the circular products, for example with the introduction of certifications [49] [50].

Co-creation and innovation with network members (9): the intermediary can be directly involved with other parties in the development of new and innovative solutions [13] [42], or in the tailoring of existing solutions to the needs of each network [22] [50].

VI. DISCUSSION

The analysis of literature has allowed the identification of nine functions that intermediaries could perform in the development of CE networks. According with the objective of this paper, the present section will discuss how the found roles can mitigate the existing barriers to CE; a summary is presented in appendix A.

Supply and demand matching (1): this intermediary function can act on three main barriers, namely the limited availability of recycling material and the uncertainty on the return flows, by ensuring that the demand of the customer is fulfilled, and through the matchmaking with the most appropriate partners can increase the collaboration, coordination, and stability of the network.

Mediation to foster collaboration (2): with the creation of facilitating conditions for collaboration, the intermediary can mitigate the lack of coordination, support, collaboration, and trust within the network, but also in the context of each company involved in the project. When the intermediary is involved in the writing of contracts, not only it mitigates these barriers, but also helps parties comply with the complex existing legislation and policies.

Asset ownership (3): when the intermediary owns assets, it can help companies in mitigating the perceived risks, both operational and financial, eliminate the need for high initial investments, and contain the potential increase in costs. If the assets owned by the intermediary include trucks, it can help increase the reverse logistics capacity, and counter the limited life span of food, if appropriate vehicles are employed. The intermediary might also own other assets, such as machineries or warehouses, that limit the lack of adequate technologies and infrastructures.

Knowledge dissemination and communication facilitation (4): the knowledge-broker function of the intermediary can help raise awareness among all stakeholders, increase the knowledge and skills on CE, and help shift companies and SCs from the linear view to a circular one, thus also acting on the existing business culture. The development of communication channels within the network helps foster the exchange of information, the coordination, trust, and support among the network participants.

Initiation and coordination of CE projects (5): when the CE project is started by the intermediary, one of its duties might be to recruit the appropriate companies to involve in the network, thus reducing the relevance of the “lack of network support, collaboration, and coordination” barrier. The centralization of the project management could also mean a better diffusion of knowledge and awareness on CE and lower perceived risks by the parties involved. If the intermediary is a representative of public institutions, the governmental support might be more clear to the companies and the projects might be tailored to appropriately fit within the existing legislation.

Flow procurement, preparation, and mobilization (6): the procurement of materials by the intermediary can help reduce the relevance of barriers such as the low cost of virgin raw materials, the limited availability of recycling materials, and the related uncertainties. If the intermediary also performs preparatory actions on the materials, the lack of technologies and infrastructures in companies becomes less prominent. When reverse logistics operations are assigned to the intermediary, the geographical dispersion of the sources and the limited capacity of reverse logistic are no longer companies’ concerns.

Foreseeing and measuring impact of CE (7): presenting in advance the possible outcomes of CE actions can mitigate the perceived risks, and measuring the real impact created by the project can help develop performance assessment systems for CE and increase the involvement and awareness of stakeholders.

Act as warrantor (8): safeguarding the interests of each of the actors involved in the network can reduce the risks perceived by companies and help build trust among members. Introducing instruments to monitor the quality of material flows, such as certifications, can lead to a better management of the product quality throughout its life cycle and to a higher quality assurance of circular products, thus more likely to meet customers’ standards.

Co-creation and innovation with network members (9): the active involvement of the intermediary in the development of tailored or new CE solutions can help increase the involvement of stakeholders, also thanks to a better information and innovation sharing on CE. Tailoring existing solutions to the specific context of a company can help better integrate them in the existing business culture.

A “circularity broker” combining these functions would be able to mitigate most of the barriers that companies face in the transition to circularity, despite some barriers would remain unaddressed. In some of the analyzed studies, the intermediary is a public institution [39] [43], meaning the barrier “Lack of incentives and governmental support” would be tackled not by the function performed but by the identity of the intermediary, which can be of different natures.

VII. CONCLUSION

This work has presented an overview of the functions an intermediary, a “circularity broker”, could play in the development of CE systems: nine functions have been identified, which have shown to have a positive impact on the mitigation of most barriers to circular food SCs. This analysis represents, to the best of authors’ knowledge, a novel contribution to theory. The framework presented in appendix A also has practical contributions, since practitioners willing to shift to circularity could use it to understand which actions an intermediary could take on to mitigate the barriers present in the context of their operations.

The main limitation of this study is represented by the small sample of records from which these considerations have been derived, that all belong to academic literature. Despite describing real CE projects, this study could benefit from the inclusion of more empirical evidence on the role of intermediaries, to confirm and eventually expand the proposed framework. Thus, a further development of the present study could be the investigation of these functions in an empirical context, to understand which are more valued by companies operating in the food industry, and if other ones are perceived as relevant.

Further research could also be devoted to the exploration of the role of intermediaries in the CE; despite the theoretical conceptualization proposed by Ciulli et al. (2019), this topic appears as understudied [13].

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