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Transforming existing local ecosystems to circular economy ecosystems for plastics

The case of the PlastiCity ecosystem

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Abstract

This paper discusses the transition toward a circular economy ecosystem (CEE) for plastics by assessing and mapping existing ecosystems and coordinating efforts among ecosystem actors. The PlastiCity ecosystem is used as a case study. The study employs ecosystem analysis and mapping to identify the new activities and actors needed to transition toward a CEE. These include local and eco-friendly transportation, plastic recycling knowledge management, and upgrading the existing recycling infrastructure. The findings emphasize the significance of the joint orchestration of ecosystem actors facilitated by an ecosystem coordinator and knowledge team to achieve a CEE. It presents a tangible and feasible approach to achieving a local plastic CEE. The policymakers are encouraged to support collaborative orchestration efforts among ecosystem actors and establish knowledge management practices that facilitate ecosystem transitions.

KEYWORDS
circular business model, circular economy ecosystem, ecosystem mapping, industrial ecology, multi-actor collaboration, plastic recycling

1 | INTRODUCTION

The existing linear economic paradigm of "take, make, and dispose" is ineffective in managing plastic waste, with a mere 9% of plastic waste being recycled globally (Geyer et al., 2017). According to the Ellen MacArthur Foundation (2017), plastic packaging material experiences a loss of 95% of its value. The current situation requires a prompt implementation of the circular economy (CE), which could facilitate economic growth independent of material extraction through closing and slowing resource loops (Blomsma & Brennan, 2017; Bocken et al., 2016; Lüdeke-Freund et al., 2019). The CE is focused on using resources sustainably to reduce waste and consumption of natural resources (de Sousa Jabbour et al., 2018; Rajala et al., 2018; Stewart & Niero, 2018) and promoting sustainable development by meeting the needs of a growing population without relying on primary resource exploitation (Circle Economy, 2022).

Despite the acknowledged challenges associated with the global implementation of the CE due to the necessity of multi-actor collaboration (Nonet et al., 2022; Schroeder et al., 2019), our study proposes advocating for the adoption of the CE at local and regional levels. Specifically, we concentrate on urban areas responsible for roughly 60%–70% of worldwide resource use, waste, and greenhouse gas emissions

(Circle Economy, 2022). However, even at the local level, successful implementation of the CE still hinges upon collaborative efforts among various stakeholders, as Hahladakis and Lacovidou (2019) emphasized. The authors underscored the significance of exchanging data, knowledge, and expertize among relevant actors.

In local CE implementation, adopting circular business models (CBMs) is essential for establishing closed-loop systems that minimize waste and enhance resource efficiency. Researchers agree that CBMs provide a tangible pathway for CE implementation, albeit necessitating a shift from a firm-centric to an ecosystem-centric perspective (Esposito et al., 2018; Fehrer & Wieland, 2020; Frishammar & Parida, 2019; Giampietro & Funtowicz, 2020; Jabbour et al., 2020; Khan et al., 2020; Zucchella & Previtali, 2019). Following this perspective, circular economy ecosystems (CEEs) are emerging, defined as "*communities of hierarchically independent yet interdependent heterogeneous sets of actors who collectively generate a sustainable ecosystem outcome*" (Aarikka-Stenroos et al., 2021).

This paper contends that engaging local ecosystem actors and aligning their activities to foster the emergence of new ecosystem activities is essential for CEE implementation. However, studies on local ecosystem responses to enable CEEs are neglected, and the literature on the transition toward CEEs is limited (Aarikka-Stenroos et al., 2021). Therefore, this study focuses on exploring the transformation of current ecosystems into CEEs through a comprehensive understanding of the actors and activity linkages in local and regional ecosystems. Hence, the main question is: *What are the key activities and actors for successfully transitioning existing ecosystems toward CEEs for plastics while fostering collaboration among ecosystem actors?*

To answer this question, this study presents a multi-site case study based on the EU-funded PlastiCity project, which seeks to combat plastic pollution and increase plastic recycling rates by revamping local ecosystems in four European cities. The results highlight the importance of actor-activity-centered ecosystem analysis and joint orchestration in supporting the transition toward CEEs and the significance of knowledge management. In addition, this study identifies the new activities, actors, and linkages required to revamp existing ecosystems toward CEEs. Finally, this paper provides policy implications for policymakers and practitioners interested in fostering the transition toward CEE for plastics.

This paper is structured as follows. Section 2 presents the research background and theoretical framework. Section 3 describes the methodology. Finally, Section 4 gives the findings, while Sections 5 and 6 provide a discussion and conclusion.

2 | RESEARCH BACKGROUND AND THEORETICAL FRAMEWORK

2.1 | Circular economy and circular business model

The CE has been developed as a response to the limitations of sustainability, challenging the linear model of "take-make-dispose" (Brozovic, 2020). In this economic system, value is created by recycling items and their components in many cycles based on closing and slowing resource loops to achieve sustainability across the product life cycle, from resource extraction through the end of life (Blomsma & Brennan, 2017; Lüdeke-Freund et al., 2019). Slowing-the-loop activities, such as repair and maintenance, reuse and redistribution, and refurbishment and remanufacturing, aim to lengthen the life cycle of a product and the usage of resources (Bocken et al., 2016; Lüdeke-Freund et al., 2019). Closing-the-loop activities, such as recycling, cascading, repurposing, and biochemical feedstock extraction, aim to close the loop between post-use and production (Bocken et al., 2016; Lüdeke-Freund et al., 2019). Figure 1 represents the resource cycles of the CE.

Businesses must adopt CBMs that balance economic value, environmental protection, and biosphere boundaries to comply with the CE (Perey et al., 2018; Zucchella & Previtali, 2019). CBMs are practical tools that can facilitate the systemic application of the CE, as they broaden the scope of stakeholders to include policymakers, research institutions, communities, and competitors (Centobelli et al., 2020; Esposito et al., 2018; Fehrer & Wieland, 2020; Frishammar & Parida, 2019; Giampietro & Funtowicz, 2020; Hofmann, 2019; Jabbour et al., 2020; Khan et al., 2020; Lüdeke-Freund et al., 2019; Perey et al., 2018; Rosa et al., 2019; Zucchella & Previtali, 2019). A CBM seeks to preserve and extend the value of a product and its constituents by utilizing resources in many cycles and minimizing waste and consumption (Hofmann, 2019; Lüdeke-Freund et al., 2019; Salvador et al., 2020) and targets either economic, environmental, or social outcomes (Fehrer & Wieland, 2020). It includes a product life cycle viewpoint because a CBM must consider the product's end-of-life prior to production (Bocken et al., 2016; de Angelis et al., 2018; Lüdeke-Freund et al., 2019; Salvador et al., 2020). Figure 2 represents the main elements of a CBM encompassing the ecosystem, the value proposition and customer and market analysis, the production process, the value delivery, the performance analysis (sustainability assessment and cost and revenue), and the outcome.

To transition from a linear to a CBM, scholars highlighted several processes, including scanning the market and sensing new business possibilities, evaluating the solutions, developing the strategy and implementing the ideal solution (Chen et al., 2020), and restructuring the organization (Khan et al., 2020). Adopting a CE requires activity planning beyond organizational boundaries, which demands that companies change their managerial perspective from firm centric to ecosystem oriented (Fehrer & Wieland, 2020; Frishammar & Parida, 2019; Jabbour et al., 2019; Kanda et al., 2021; Parida et al., 2019; Zucchella & Previtali, 2019). Therefore, researchers have included an ecosystem assessment in their transition process model toward a CBM (Frishammar & Parida, 2019; Parida et al., 2019).

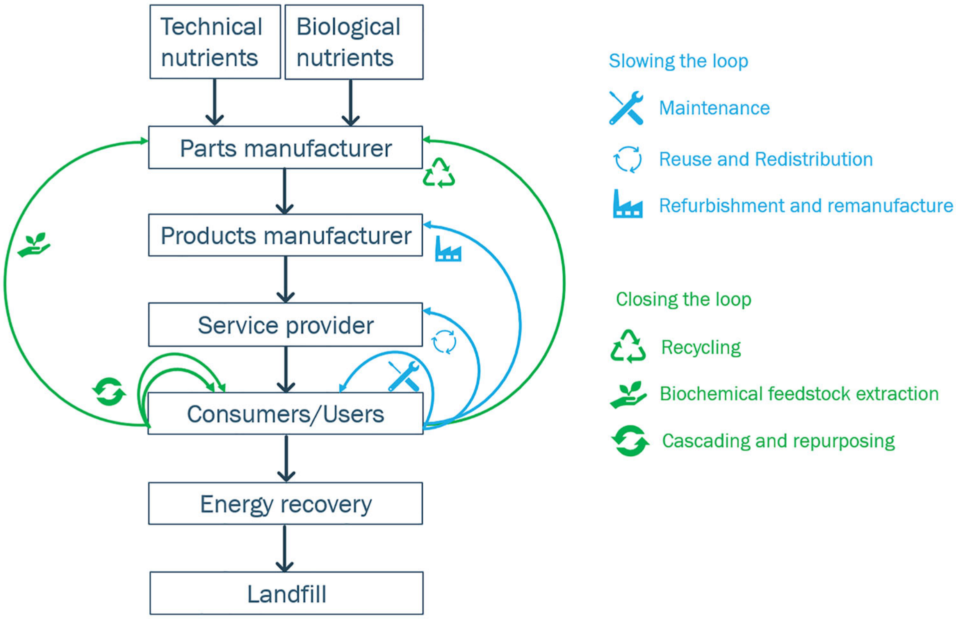

FIGURE 1 Resource cycles of the circular economy adapted from Ellen MacArthur Foundation (2013) and Lüdeke-Freund et al. (2019).

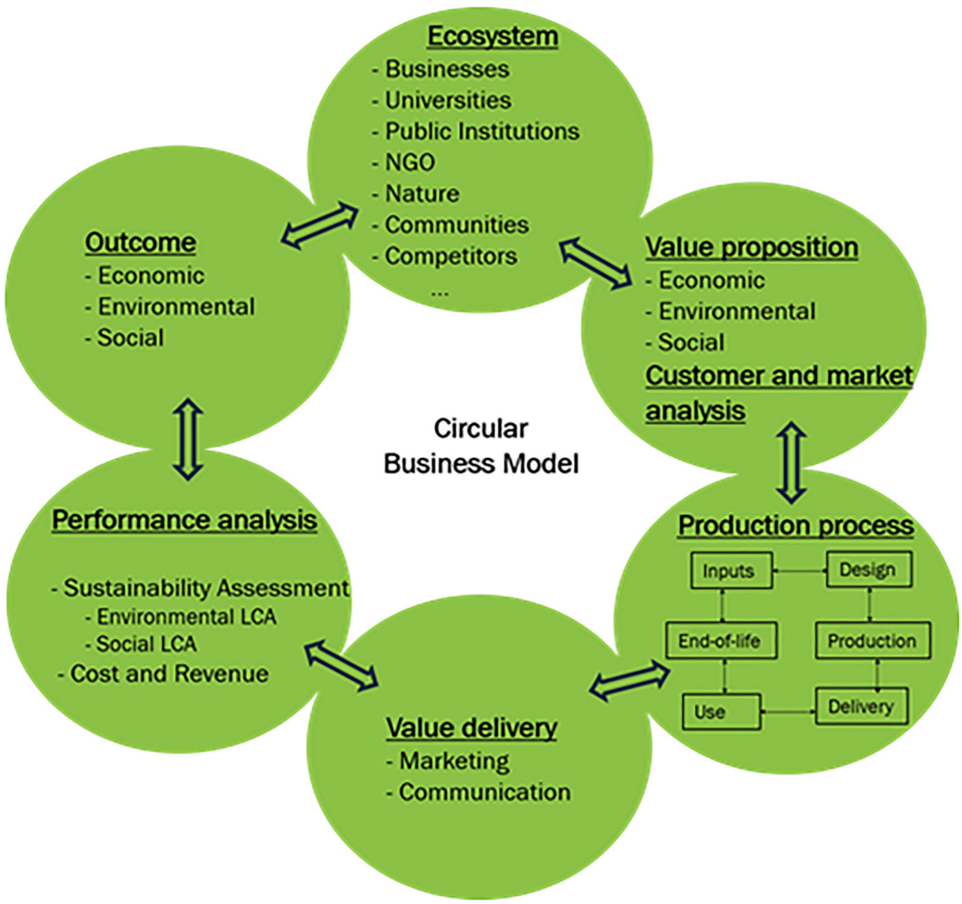

FIGURE 2 Circular business model Elements. *Source*: Own.

2.2 | Circular economy ecosystem

By adopting the "ecosystem" approach, companies can comprehend the intricate network of stakeholders and visualize how their business activities affect scopes beyond their firm and industry boundaries (Aarikka-Stenroos et al., 2021; Adner, 2017; Geissdoerfer et al., 2020; Kanda et al., 2021). The CE and the "business ecosystem" approach have origins in industrial ecology, which compares the business environment to a biological ecosystem (Geissdoerfer et al., 2020; Ghisellini et al., 2016; Kanda et al., 2021; Moore, 1993, 1996).

Initially, ecosystems referred to intentional communities of affiliated and interacting firms brought together by the need for ongoing innovation and co-evolution (Moore, 1993, 2006). Recent research has introduced new conceptualizations. For instance, ecosystems can be categorized based on strategic objectives, such as innovation, knowledge, or entrepreneurial activity (Llewellyn & Autio, 2020). Alternatively, an ecosystem can be described based on its structural and functional characteristics, formed by multiple aligned organizations that work together to achieve a specific ecosystem-level value proposition (Adner, 2017; Jacobides et al., 2018).

Facilitating the shift toward a CEE requires multi-organizational coordination, such as changing flows of material, energy, and value on an ecosystem level (Aarikka-Stenroos et al., 2021). While the concept of "ecosystem orchestration" has been discussed in strategic management research, it has received little attention in the context of CE (Autio, 2021; Mann et al., 2022; Parida et al., 2019). Previous research in CE has primarily focused on exploring internal interactions and critical activities within a single organization to facilitate the transition toward a CE (de Langen et al., 2020; Staicu & Pop, 2018). However, few studies have adopted an ecosystem perspective to examine activities and interactions across multiple organizations (Hannah & Eisenhardt, 2018; Hou et al., 2020).

2.3 | Ecosystem orchestration

Ecosystems are self-sustaining (Fuller et al., 2019; Pidun et al., 2019), but they are also constrained by institutional barriers, such as regulations, social norms, and cognitive models (Moore, 1996; Scott, 2014). Overcoming these barriers and facilitating ecosystem transition requires the modification of role distribution, responsibility allocation, and prevailing industry mindsets (Spender, 1989). This transformative process lies at the core of ecosystem strategizing, and it becomes crucial to comprehend and address potential resistance to ecosystem transition to orchestrate the ecosystem effectively.

"Ecosystem orchestration" involves a firm proactively offering value to establish a desired ecosystem architecture (Autio, 2021) by maintaining, disrupting, and changing institutions (Vargo et al., 2015) or by proposing a joint value proposition to align the needs of all partners (Lingens et al., 2021). An ecosystem can be considered a resource base for strategic orchestration (Hou & Shi, 2021).

Various ecosystem strategy frameworks, such as those proposed by Adner (2017), Talmar et al. (2018), and Tsvetkova et al. (2017), highlight the importance of actor- and activity-based understandings for ecosystem orchestration. Activities represent specific actions that reflect the value proposition a company aims to achieve, while actors are the entities responsible for carrying out these activities (Adner, 2017).

The interdependency between actors and activities in an ecosystem is crucial for value creation and capture. Adner (2017) defined four elements for understanding ecosystems as a strategic structure: activities, actors, positions, and links. Links refer to the transactions, such as material, information, or value transfers across actors. Several visual tools have been developed to visualize the actors and activities of an ecosystem: the ecosystem activity map (EAM) proposed by Tsvetkova et al. (2017) and the ecosystem pie model (EPM) designed by Talmar et al. (2018). The former highlights the importance of considering activities and stakeholders to achieve the ecosystem objective. The latter emphasizes how ecosystem actors create and capture the value and rely on the ecosystem value proposition regarding resources and activities.

Despite extensive theoretical frameworks, empirical research on existing ecosystem orchestration is rare. Therefore, this paper assumes that understanding actor and activity linkages within an ecosystem could serve as a basis for ecosystem orchestration and support the current ecosystem structure transition to CEE.

3 | METHODOLOGY

3.1 | Research context

The focus of this study is the PlastiCity project, a European initiative aimed at increasing plastic recycling rates in the 2-Seas region from 20%—30% to 50%. The project is part of a broader European effort to develop a CE for plastic, which aims to reuse plastic waste as a secondary resource to keep it in the resource loops (Davidson et al., 2021; European Commission, 2018). More precisely, PlastiCity targets "lost plastics": the large amounts of recyclable plastic waste produced by businesses that are not currently recycled. The project is implemented in four pilot cities: Southend-on-Sea, United Kingdom (UK); The Hague, Netherlands (NL); Douai, France (FR); and Ghent, Belgium (BE).

From 2019 to 2022, 13 PlastiCity partners worked together to develop new strategies for localizing, collecting, recycling, and reusing lost plastics:

- BE: D.P.L. Group Plastic Recycling, GRCT, Van Werven, University of Ghent and The City of Ghent
- FR: WeLoop, Team2, Theys Recyclage and Armines
- UK: University of Portsmouth and Southend-on-Sea City Council
- NL: Metabolic and The Municipality of The Hague

The project aimed to conduct a comprehensive mapping of the actors involved in the plastic value chain and plastic flows, develop novel logistic and processing scenarios, produce new CBMs for the new value chains derived from lost plastics, and design urban platforms and new products (vases, plastic films, claddings, and nose bridges). Furthermore, the project sought to establish a mobile pre-treatment unit and develop facilities for recycling hubs.

3.2 | Data collection

The project setup of PlastiCity in multiple cities and the nascent transition toward CEE led us to design our research as a multi-site case study (Creswell, 2007). The project is considered a single case carried out in different locations. A multi-site case study captures the specific transition phenomenon toward CEE into each location's context, comprehensively describing the findings (Audet & d'Amboise, 2001; Gillham, 2000; Yin, 2018). Moreover, a multi-site case study enables comparison similar to a multi-case study (Eisenhardt & Graebner, 2007; Gibbert et al., 2008; Gioia et al., 2013). Instead of cross-case generalization, a multi-site study yields cross-site generalization and enhances empirical reproducibility of the phenomenon for a more extensive application of CEE transition.

This paper presents a longitudinal participant–observational case study of the PlastiCity project ecosystem, using observation and participatory action research for data collection. The researcher was a participant–observer (Yin, 2018), observing and influencing the project partners' work while simultaneously engaging in the activities. The researcher participated in various PlastiCity Work Packages (WP) deliveries and meetings (steering committee, annual, and regional meetings). Action research is an inquiry with people instead of research on people (Altrichter et al., 2002). The action research involved a working group comprising an intern from the Municipality of The Hague, a business consultant from Van Werven, and a co-author of this paper, all partners of PlastiCity. Action research involves a cyclical process of observation and reflection (Altrichter et al., 2002). The first cycle occurred in October 2020, when we developed the recycled face shield CBM. The context of the action research is the design of CBMs as a critical output of the PlastiCity project. In November 2020, the second action research cycle began as the co-researchers and the co-author realized that creating partnerships between stakeholders of the plastic value chain was the main issue in implementing local CBMs. We aimed to solve this issue by designing a PlastiCity ecosystem. Afterward, we entered the third action research cycle related to "acting on knowledge" (Saunders et al., 2019) in January 2021. This involved engaging with various partners and external stakeholders to discuss the implementation of the PlastiCity ecosystem. They also contributed a book chapter presenting their work in more depth (Litaudon et al., 2023). Furthermore, throughout the action research, the researcher recorded her observations, interactions, and emotions in fieldwork notes to facilitate substantial self-reflection (Coghlan & Shani, 2005; Kemmis et al., 2014), relevant in understanding the emergence of the PlastiCity ecosystem and the partners' challenges in implementing local CBMs.

Additionally, the researcher interviewed 14 PlastiCity partners working on CBMs (Table 1) to gain insights into their experiences developing new CBMs, the factors that drove the creation of new CBMs, and the challenges and motivations involved in collaborating with various actors. These interviews provided a more profound understanding of the difficulties in implementing local CBMs.

3.3 | Data analysis

This study first employed open coding to analyze the meeting minutes, interview transcripts, and field notes from the observation and action research to identify the critical challenges faced by partners during the implementation of CBMs. Then, the analysis focused on the PlastiCity ecosystem developed as part of the action research. Based on the research questions and background, the researchers considered two visual tools for the data analysis: EPM (Talmar et al., 2018) and EAM (Tsvetkova et al., 2017). EPM gathers complex business strategy elements such as resources, inter-organizational dependencies, and risks. The selected case project focused on an ecosystem's initiation stage, and the actors lacked in-depth knowledge regarding potential business risks; therefore, the EAM proposed by Tsvetkova et al. (2017) was adopted for this study (Figure 3).

The EAM has four layers (Tsvetkova et al., 2017):

1. The ecosystem goal refers to the common objective for the focal ecosystem;
2. Functional outputs are core competencies for fulfilling the ecosystem goal (Porter, 1996);

TABLE 1 Table of interviews.

PlastiCity partners (country)	Organization type	Actor role
Southend-on-Sea City Council (UK)	Government representative	Project officer A
	Government representative	Project officer B
	Government representative	Project manager
Municipality of The Hague (NL)	Government representative	Program manager
	Government representative	Project manager
	Government representative	Consultant
	Government representative	Student—intern
Van Werven (BE)	Plastic feedstock producer	Consultant
DPL (BE)	Recycler	Project manager
Ghent University (BE)	Knowledge institution	Lecturer–researcher
Theys Recyclage (FR)	Waste management	Director
Team 2 (FR)	National competitiveness cluster	Project manager
Team 2 (FR)	National competitiveness cluster	Project officer
Armines (FR)	Knowledge institution	Lecturer–researcher

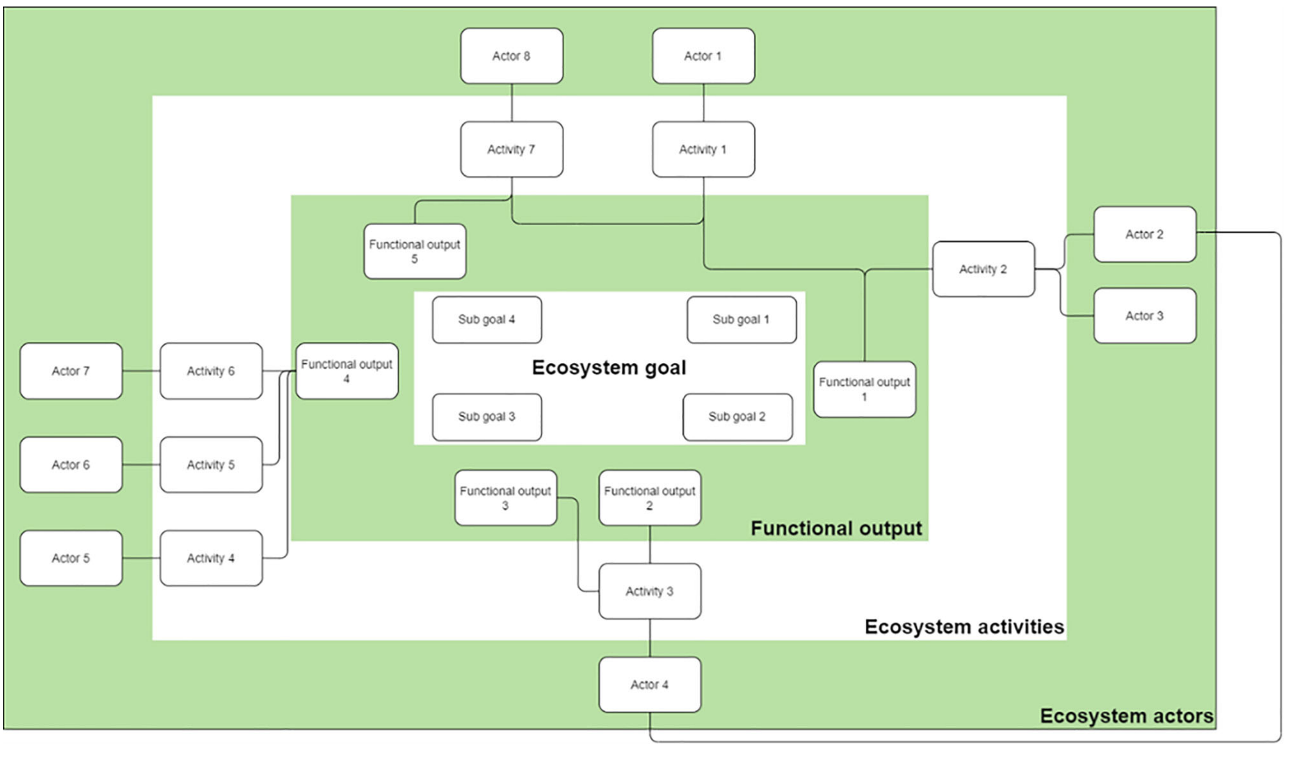

FIGURE 3 Ecosystem activity map example. *Source*: Tsvetkova et al. (2017).

3. Ecosystem activities are actions taken to achieve functional outputs;
4. Ecosystem actors are entities that undertake the activities. This layer aims to understand ecosystem orchestration and governance.

The lines between layers refer to the ecosystem links Adner (2017) mentioned, which depict the relationships between elements, cross-layers, and interactions between actors. First, we started by identifying the PlastiCity ecosystem goal and functional outputs. Second, we mapped the ecosystem's existing elements (activities and actors). Third, we identified common activities and actors that changed in their transition toward CEEs or missing ecosystem elements. Finally, we categorized and discussed the changes and missing ecosystem elements to align empirical observations

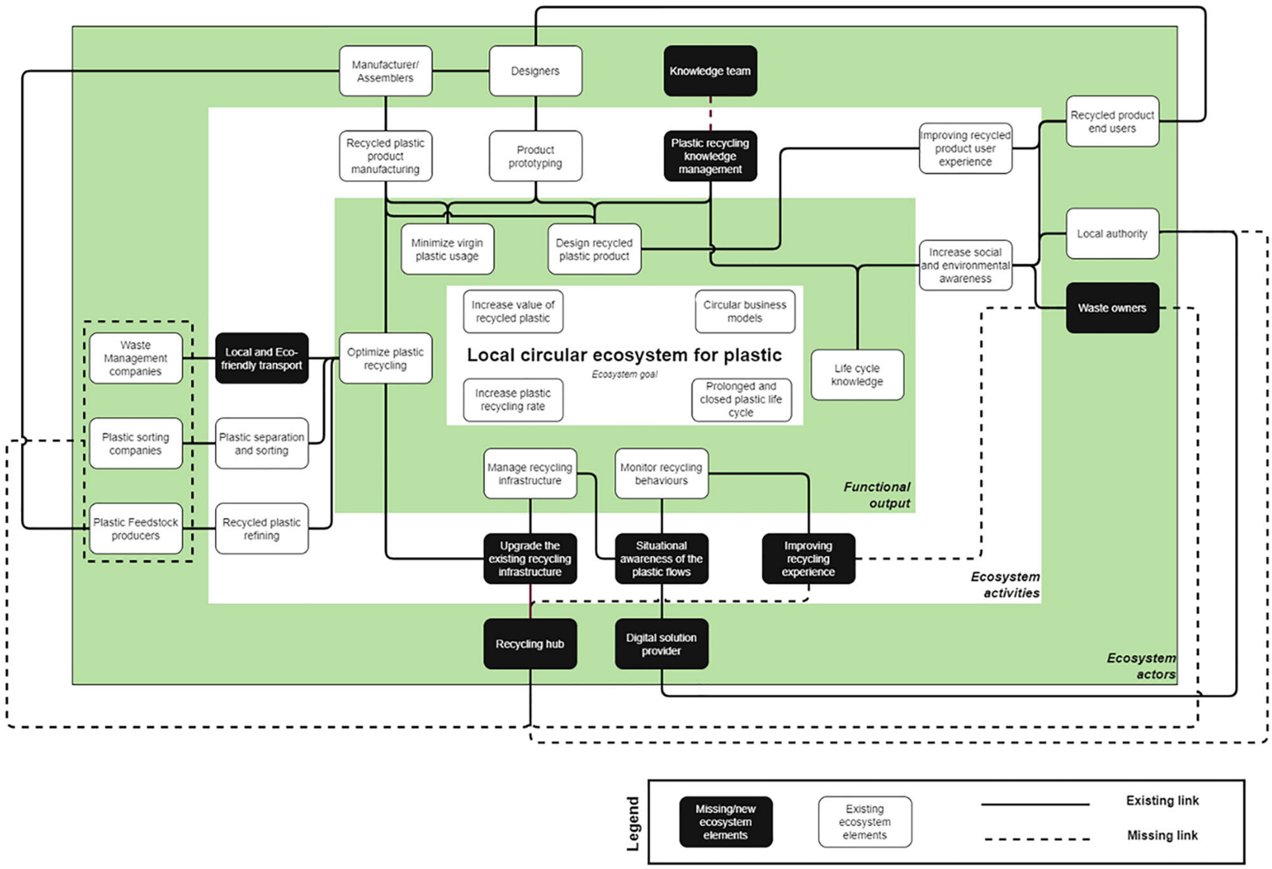

FIGURE 4 The PlastiCity ecosystem activity map. *Source*: Own.

with theoretical backgrounds. This allowed the researchers to identify key factors and patterns relevant to successfully implementing CEEs in local ecosystems and to understand how these factors interact.

4 | FINDINGS: THE PLASTICITY ECOSYSTEM MAPPING

The PlastiCity consortium has played a pivotal role in developing regional CEEs for plastic that promote and facilitate novel CBMs within the plastic value chain. This has been achieved by addressing the obstacles to establishing new CBMs, particularly those related to cross-sectoral and multi-stakeholder collaboration. "*With the companies, the main struggle there is that they don't collaborate with each other. They see each other as competition*" (BE, Ghent University). Cross-sector actors do not consider collaborating as they lack common interests or have different understandings and interests regarding plastic recycling. "*I think also it's difficult to get different sectors working with each other. [...] it would be quite difficult, they don't have anything in common*" (UK, Southend-on-Sea City Council). Therefore, the PlastiCity partners established regional ecosystems to facilitate such cooperation.

Following the EAM instructions, the PlastiCity EAM is presented in Figure 4. Since the current activities could not fulfil all the functional outputs in the emerging local CEE, the authors realized "missing ecosystem activities." Hence, new ecosystem activities are mapped in dark boxes, requiring new actors and links, mapped in dotted lines.

The PlastiCity project aims to create a *local CEE for plastic*, increasing the *recycling rate* and *value of recycled plastic*. More precisely, the ecosystem aimed at *implementing local CBMs* within the plastic value chain and *prolonging and closing the plastic life cycle*.

To comprehend the total ecosystem activity and facilitate new partnerships, the PlastiCity partners reached out to ecosystem actors: "*In these conversations, we'll get more like a picture [of] what we are doing, what they need, how we can work together*" (NL, Municipality of The Hague).

Several functional outputs are required to fulfil the ecosystem's goal. Critical functional outputs for closing the plastic life-cycle are *minimizing the usage of virgin plastic*, optimizing the plastic recycling rate, managing recycling infrastructure, and *monitoring recycling behavior*. In order to prolong the life cycle of plastic, it is imperative to optimize the value of recycled plastic products via enhanced design and a more comprehensive understanding of the life cycle of plastic items. The functional outputs are interdependent, and all are necessary for achieving the ecosystem goal.

TABLE 2 Comparative table of each city ecosystem.

City	Urban platform	Recycling hub	Ecosystem coordinator	Knowledge team
Ghent	A website, "Invest in Ghent" and LinkedIn "Invest in Ghent"	An industrial recycling hub at the North Sea Port Business Park, operated by the city council, local businesses, and the University of Ghent	Ghent City Council	Ghent University, *Van Werven, GRCT, DPL*
The Hague	A LinkedIn group administrated by the plastic hub	Circular plastic hub operated by The Municipality of The Hague and local entrepreneurs	The Municipality of The Hague	*Van Werven*, Ghent University, *CargoBike*
Southend-on-Sea	A PlastiCity Pledge Recycling Forum administrated by the local authority	Virtual hub and six physical mini-recycling hubs in schools and businesses, operated by the City Council.	Southend-on-Sea City Council	*Van Werven*, University of Portsmouth
Douai	An existing platform, ACTIF operated by the Chamber of Commerce and Industry Hauts-de-France	A sorting plant including a plastic hub for plastic waste operated by Theys Recyclage	Team 2	*Armines, Theys Recyclage, WeLoop*, University of Portsmouth

4.1 | Existing ecosystem elements

There are already ecosystem activities that contribute to one or more functional outputs. For example, *manufacturing and prototyping* based on recycled plastics can minimize virgin plastic usage, optimize the plastic recycling rate, and design recycled plastic products. Designing recycled plastic products is also addressed by *improving the user experience of recycled products*. Other activities include *plastic separation and sorting, recycling and refining, and promoting social and environmental awareness*.

To execute these activities, the current ecosystems encompass various actors such as municipal authorities, recycled product consumers, designers, manufacturers, waste management and plastic sorting companies, and plastic feedstock producers. Plastic sorting enterprises focus on the segregation and sorting of plastic materials. In contrast, plastic feedstock manufacturers play a pivotal role in enhancing the quality of recycled plastic by producing recyclates. The designers and manufacturers are responsible for creating product prototypes. The designer can enhance the recycled product experience for the end-users. This link can improve recycled products' value by enhancing product quality and the ability to conform to the end-user's specific requirements.

4.2 | Missing ecosystem elements

The results show that new activities in the ecosystem are required to contribute to the functional outputs. *Plastic knowledge management* could support social and environmental awareness activities. Plastic knowledge management and social and environmental awareness could enable accessing plastic life cycle knowledge. Similarly, the new CEE requires monitoring and managing recycling infrastructure and behavior. Hence, it is necessary to upgrade the *existing recycling infrastructure, increase situational awareness of the plastic flows, and improve the recycling experience for the residents*. These activities are interdependent because recycling infrastructure upgrading can directly improve the recycling experience. The infrastructural upgrade is not limited to physical but also digital capacity upgrades so that the relevant ecosystem actors can be aware of the plastic flow situation in real time within and around the city.

The knowledge team is crucial in the plastic life cycle knowledge management, which can accelerate plastic CEE implementation. Within the four PlastiCity pilot cities, each knowledge team comprises at least one member from the academic, public, and private sectors. Their primary responsibility is to assess new partnerships' viability by investigating potential risks and solutions. As a PlastiCity partner mentioned: "*The knowledge team gives advice for new solutions and opportunities and risks. [. . .] Investigates and research new relations and links to partners*" (January 8, 2021, fieldwork, WP3 face shield business case meeting). When developing the recycled face shields CBM, a knowledge team assisted ecosystem coordinators in understanding the technical aspects of manufacturing face shields.

While designing the PlastiCity ecosystem, partners highlighted the need for an *ecosystem coordinator* for facilitating ecosystem actor collaboration. The partners highlighted that engaging with external stakeholders is time consuming and resource intensive. It often requires an individual to take a personalized approach to understand the stakeholders' needs and expectations, which can be challenging given the limited resources available. "*We need someone to go to every business and go there and say like [. . .] this is what we're doing and what do you want, what do you need. So some sort of extra person in the team who would carry out all that work*" (NL, Municipality of The Hague).

In PlastiCity, the coordinator was from a local authority, except the French region. A coordinator's responsibility is identifying and creating synergies among local actors. For instance, the Municipality of The Hague facilitated the connection between a 3D printing company and the hospital for

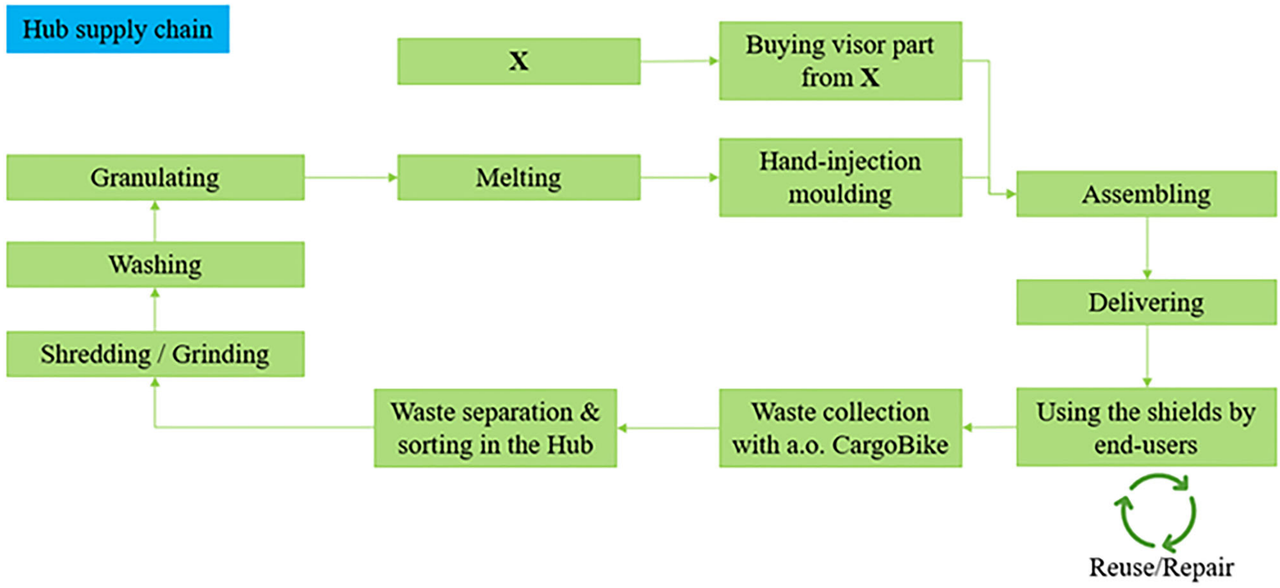

FIGURE 5 The recycling hub supply chain to produce recycled face shields. *Source*: Own.

developing recycled face shields during the Covid-19 pandemic. "*Initiating at the process starts and then further on indeed facilitate*" (NL, Municipality of The Hague). We observed that the coordinator often lacked expertize. Consequently, the knowledge team provided its knowledge to facilitate partnerships. "*The coordinator can come back to the knowledge team when they find new ideas… to make sure it is feasible*" (December 4, 2020, fieldwork, WP3 face shield business case meeting).

In PlastiCity, new physical and digital setups are emerging for ecosystem actors to engage. Before the PlastiCity project, recycling spaces were only located in suburban areas. For recycling companies, to be profitable, they only collect a large quantity of waste and for legal reasons are often located outside the urban environment. It is not economically viable to separate and recycle a limited amount of waste for producing recycled face shields. "*Are you processing our waste, and is it possible to separate? […] machinery cannot do it as needs at least 50 T of the stream but can give the same quality*" (November 22, 2021, fieldwork, WP3 meeting, discussion between the Municipality of The Hague and Van Werven). Therefore, it was often challenging to create new local and closed value chains for plastic waste. Moreover, partners emphasized shipping waste internationally is simpler and more cost effective than recycling locally. "*It is easier to send to China than Leeds. We are in a weird world*" (October 22, 2021, Fieldwork, UK WP3 business case meeting).

Placing recycling points in easily accessible places could raise plastic recycling rates and facilitate new circular activities' development. Hence, *digital solution providers* and *recycling hubs* are inputting new functions into the ecosystem.

The recycling hub is a multifunctional space providing diverse functions for the local plastic CEE. First, it allows businesses to produce recycled plastic items. Businesses can bring recyclable waste and access to recyclates for producing new plastic products. This also allows actors to recycle a limited amount of waste. For instance, the PlastiCity partners implemented a hub-based supply chain to create recycled face shields (Figure 5).

Second, it is also a waste plastic storage that collects, gathers, and reintroduces local plastic waste into the recycling system on a regional and a national scale.

Third, recycling hubs are spaces for exhibitions and education to increase the social and environmental awareness of plastic recycling. "*Recycling hub: […] Physical aspect of the urban platform which is a digital one. […] Recycling hub aims to give citizen awareness*" (January 8, 2021, fieldwork, WP3 face shield business case meeting). The local authority contributes to increasing social and environmental awareness of plastic recycling among end-users and plastic waste owners.

The recycling hub plans to update the existing recycling infrastructure and enhance the recycling experience for waste owners. Initially, *waste owners* were excluded from the ecosystem configuration. In this new ecosystem, they will sort and bring their waste to the hub, while the *local authorities* will overview and facilitate recycling awareness. While mapping the ecosystem, we observed linking waste owners with ecosystem activities and actors can enhance their recycling experience, hence, motivating them to recycle.

While developing a local and CBM for the recycled face shields, partners realized the difficulties in engaging with actors and creating synergies between them. "*What are the players, what are the tools? […] Lots of players, how do we manage it? Digital plus real platform can help to connect everyone*" (January 20, 2021, fieldwork, WP3 face shield business case meeting). Therefore, partners developed urban platforms to foster interactions between ecosystem actors. It supports data management for the product life cycle and supply chain, allowing the plastic value chain actors to pinpoint the resource's location. For instance, ecosystem actors could disclose plastic waste types that they generate or require for manufacturing. In addition, actors would locate plastic waste more easily, facilitating its recycling and usage as secondary material. The actors will gain plastic flows' situational awareness thanks to the urban platform created by the digital solution provider in collaboration with local authorities.

In the new ecosystem, the *manufacturer and the plastic feedstock producer* work together to produce recycled plastic products, and waste management companies contribute to *local and eco-friendly transport*. For instance, in The Hague, an electronic bike company (CargoBike) collected plastic waste from waste owners to the recycling hub and transported the recycled face shields to the end-users.

Table 2 summarizes each city's main components of the new PlastiCity ecosystem, including the urban platform, recycling hub, ecosystem coordinator, and knowledge team.

5 | DISCUSSION

5.1 | Theoretical implications

This paper aims to understand the activities and actors required to revamp the existing ecosystems toward CEE by understanding ecosystem activities and actors' relationships. This paper confirms that actor-activity-centered ecosystem analysis and joint orchestration by ecosystem actors could support the transition toward CEEs. The study shows that when combined with "joint orchestration" by ecosystem actors (i.e., individuals, organizations, and institutions involved in the CEE), this approach can facilitate the transition to a CEE. In other words, by analyzing the actors and activities involved in the ecosystem and coordinating efforts among them, the transition to a CEE can be more effective.

We applied the EAM to identify the existing and missing elements in the local ecosystem and highlight new activities and actors needed to transition to a CEE. The ecosystem mapping highlights new activities such as local and eco-friendly transportation, plastic recycling knowledge management, upgrading the existing recycling infrastructure, situational awareness of the plastic flow, and improving the recycling experience. The mapping also presents new ecosystem actors: recycling hub, digital solution provider, waste owners, and knowledge team. The mapping shows that the ecosystem elements are interconnected, each performing a distinct role in achieving the goal of creating new local and circular value chains through collaboration and new partnerships. This study confirms the importance of ecosystem assessment and mapping as a concrete first step to creating CBMs (Fehrer & Wieland, 2020; Frishammar & Parida, 2019; Jabbour et al., 2019; Kanda et al., 2021; Parida et al., 2019; Zucchella & Previtali, 2019). Assessing, mapping, and orchestrating the local ecosystems in the four regions of PlastiCity facilitated partners in creating new CBMs within the plastic value chain. The findings contribute further to the CBM literature by confirming the critical role of an ecosystem coordinator (Parida et al., 2019; Zucchella & Previtali, 2019) and showing that an ecosystem coordinator can be from various sectors (academic, public, or private institutions) and should be accompanied by a knowledge team.

By emphasizing the critical importance of a knowledge team in transitioning to a CEE and orchestrating the ecosystem, this study contributes to the strategic ecosystem literature. The significance of knowledge sharing in guiding an ecosystem transition has not been adequately emphasized in the current literature. We argue that a knowledge team is necessary to transform the existing ecosystem into a CEE and expand the knowledge scope on the material and product life cycle, prolonging the plastic life cycle for value creation.

Moreover, the joint orchestration expands the knowledge scope on the material and product life cycle, which prolongs the plastic life cycle for value creation. Similarly, sufficient knowledge of recycled product consumption would consequentially increase the value of recycled products so that the customers could appreciate the products more, and the manufacturers or designers would be more motivated to produce further recycled plastic products. Similar observations were obtained in previous studies regarding CEE and CBM implementation (Aarikka-Stenroos et al., 2021; Camacho-Otero et al., 2018; Kanda et al., 2021).

Overall, this study adds to the broader discussion in the industrial ecology literature on CE and its concrete implementation (Blomsma & Brennan, 2017; Corvellec et al., 2022; Leipold et al., 2022) by proposing a concrete and practical way to move toward a CE for plastics at a local level. We present a model of a local CEE for plastic that can be replicated in other regions. It identifies the essential components of a CEE for plastic represented in Figure 6, such as ecosystem actors, recycling hub, urban platform, ecosystem coordinator, and knowledge team. The PlastiCity ecosystem consists of physical and digital locations to promote the interchange of data, information, and resources among ecosystem actors (Aarikka-Stenroos et al., 2021). We consider that these ecosystem elements are essential for developing connections and partnerships among ecosystem actors and represent the critical components of a local CEE for plastic.

5.2 | Policy implications

As highlighted in the case study, policymakers play a crucial role in developing new recycling infrastructures, such as recycling hubs and new urban platforms, in raising awareness, and encouraging multi-actor collaboration. This study also demonstrates that policymakers possess the potential to serve as pivotal ecosystem coordinators.

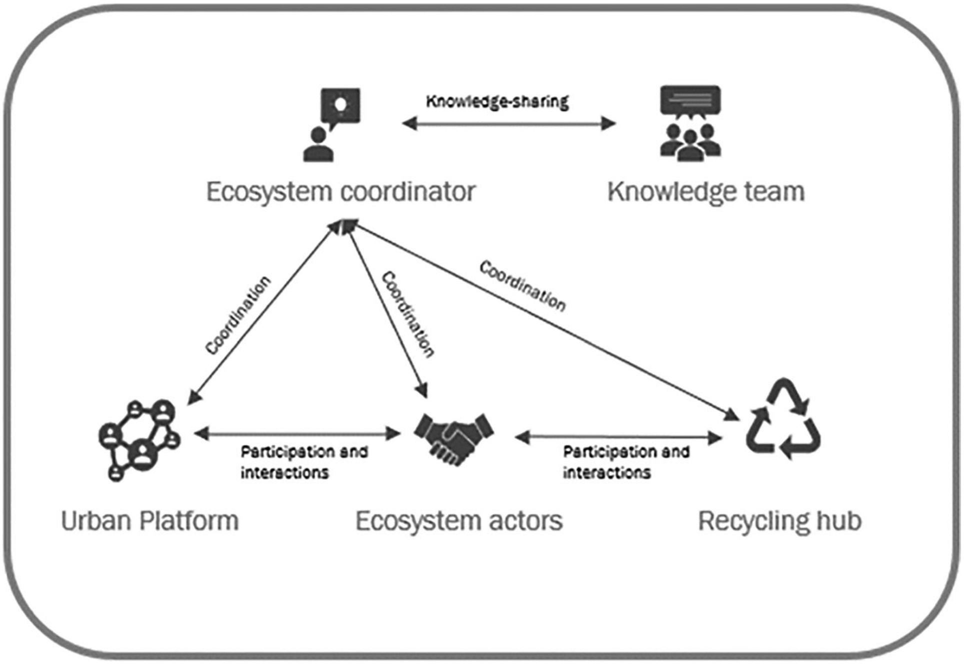

FIGURE 6 Local ecosystem. *Source*: Own.

Additionally, policymakers could facilitate the creation of local CEEs by supporting joint orchestration efforts among ecosystem actors. This can involve providing funding, guidance, and other resources to help actors work together to identify missing elements and develop new activities and partnerships. Another implication pertains to developing and promoting knowledge management practices to support ecosystem transitions by facilitating the formation of knowledge teams and providing resources to assist ecosystem actors in sharing information and expertize. Policymakers can also support ecosystem assessment and mapping efforts to identify missing elements and opportunities for new circular value chains by providing resources and support for ecosystem mapping initiatives and promoting the use of tools such as EAM.

6 | CONCLUSION AND FUTURE RESEARCH

This study analyzes the necessary activities and actors in the transition toward CEEs for plastics by analyzing their relationships. A joint orchestration by ecosystem actors and an actor-activity-centered ecosystem analysis can effectively support the transition to CEEs. The study contends that a knowledge team and an ecosystem coordinator are required to transform the existing ecosystem into a CEE and that policymakers play a crucial role in supporting joint orchestration efforts among ecosystem actors and knowledge management practices. Policymakers can support ecosystem assessment and mapping initiatives to identify missing elements and opportunities for new CBMs.

In addition, this paper emphasizes the limitations of current ecosystem mapping tools, which lack a systemic approach that considers all potential ecosystem actors. In PlastiCity, the partner sought a systemic approach by involving all actors in the plastic value chain or those who may be affected by new activities. However, the current mapping focuses only on actors directly contributing to ecosystem activities (Tsvetkova et al., 2017) and omits the vital function of the ecosystem coordinator. Therefore, new graphic representations that adopt a systemic perspective where no focal firm organizes the ecosystem and considers all actors affected by the newly generated values are necessary. For instance, researchers may add systemic design to incorporate a more systemic perspective by considering actors that the newly generated values may affect, which would also be more consistent with CBM principles (Fehrer & Wieland, 2020; Frishammar & Parida, 2019; Zucchella & Previtali, 2019).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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