

Implementing industrial and territorial ecology

The role of proximity and intermediaries in three French case studies

André Torre¹ | Sébastien Bourdin²  | Sabrina Dermine-Brulot³ | Maël Jambou³

¹University Paris-Saclay, INRAE, Agroparistech, Paris, France

²EM Normandie Business School, Metis Lab, Caen, France

³University of Technology of Troyes, UR InSyTE, Troyes, France

Correspondence

Sébastien Bourdin, EM Normandie Business School, Metis Lab, France.
Email: sbourdin@em-normandie.fr

Editor Managing Review: Jinping Tian.

Abstract

This article explores the challenges companies face when establishing cooperative relationships to implement industrial ecology initiatives. It examines the effectiveness of methodological devices in fostering inter-firm relations and creating a favorable environment for executing industrial ecology strategies. The theoretical framework of proximities is used to analyze the nature of the connections that form between firms based on these strategies. Based on interviews and social network analysis from three case studies in France, the study concludes that geographical proximity is important for cooperative relationships, but it is not enough on its own. The activation of organized proximities requires intermediary actors and methodological devices. In addition, these collaborations need consistent and effective support to ensure their long-term sustainability; without such support, they tend to be short lived.

KEYWORDS

circular economy, geographical proximity, industrial and territorial ecology, inter-firm collaboration, organized proximity, territorial intermediation

1 | INTRODUCTION

Environmental concerns, such as resource conservation, biodiversity protection, and global warming, are becoming strategic priorities for companies (Sundaram & Hansen, 2023). In response to the limitations of traditional linear production methods, first identified by Boulding (1966), multiple concepts have emerged to reconcile economic growth with environmental and social well-being. While these concepts have shaped public policies globally, their translation into tangible actions by companies remains challenging (Sundaram & Hansen, 2023).

The circular economy (CE), an economic model inspired by natural ecosystems, is a prominent response to these challenges. Widely institutionalized in Europe since the creation of the Ellen Mac Arthur Foundation in 2010, CE is translated into a set of strategies for companies and consumers. They promote resource efficiency, waste minimization, and resource reuse (Hachaichi & Bourdin, 2023; Kirchherr et al., 2017), and thus offer companies a means to create sustainable value locally (Lewandowski, 2016; Niang et al., 2023). These strategies include the creation of industrial symbiosis which implement synergies among companies, converting one's waste into another's resources (Bourdin & Torre, 2020; Veysière et al., 2022). Industrial symbiosis has been defined by Chertow (2007) as "engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchanges of materials, energy, water and/or by products." They are part of operational industrial ecology strategies promoted by academic scholars (for instance, Awan, 2022; Kohronen, 2001) in order to transform traditional industrial systems into industrial ecosystems inspired from the cyclic functioning of natural ecosystems (Frosch & Gallopoulos, 1989).

In France, industrial symbiosis is commonly referred to as industrial and territorial ecology (ITE) strategies. Over the last 15 years, French research on ITE has been predominantly led by social scientists, particularly in the disciplines of economics and regional science, concentrating on social, organizational, and territorial dimensions (Beaurain & Brulot, 2011; Brulot et al., 2014; Buclet, 2021; Maillfert & Schalchli, 2010). This body of research stresses that ITE extends beyond technical matters and is deeply intertwined with human and organizational factors, with specific

focus on relational contexts, trust, cooperation, and institutional proximity (Cerceau et al., 2018; Jambou et al., 2022; Patala et al., 2020). French scholars have particularly highlighted the significance of intermediation, in contrast to market-driven solutions like the National Industrial Symbiosis Program (NISP) model, which has been predominant in other contexts (Brulot, 2009; Maillfert & Schalchli, 2010). The French perspective emphasizes the crucial role of territorial facilitators who serve as intermediaries to promote collaboration among local stakeholders. This distinctive approach to ITE in France underscores the pivotal role of intermediaries, collective learning, and geographical and organized proximity in the success of ITE strategies. Additionally, French research has been instrumental in shaping new economic models, such as ITE and the Economy of Functionality, which have been incorporated into public policies, notably through ADEME's¹ initiatives. These models are explicitly referenced in the French Circular Economy Roadmap and the 2020 AGECE law, illustrating the institutional recognition of these approaches as fundamental to the ecological transition.

Nevertheless, despite these advancements, studies continue to underscore the challenges in implementing ITE strategies, often stemming from a lack of incentives and the difficulty in organically fostering collaboration between industrial stakeholders without the intervention of a territorial facilitator or readily identifiable local partners (Bourdin et al., 2022). The involvement of these intermediaries is therefore regarded as crucial for overcoming these obstacles and expanding ITE strategies across diverse territories.

Given the necessity and complexity of inter-company cooperation in CE (Gallego-Bono & Tapia-Baranda, 2022; Jambou et al., 2022), it is determinant to examine the role played by intermediaries in implementing ITE strategies and observe how public bodies can promote them. With this objective in mind, the analysis focuses on the "methodological devices" developed by private companies and used at the territorial level to enhance ITE strategies. Methodological devices are tools used by local actors to implement ITE and foster collaborative relationships. They aim to bring together potential ITE actors, identify common interests, overcome barriers, and support cooperation processes, thus facilitating the development of circular economy methods (Belaud et al., 2019). In France, ITE projects characterized by local cooperative interactions are being implemented by private companies and supported by public players, notably ADEME. These initiatives seek to create synergies, which means collaboration between companies to achieve a circular flow of resources (Hewes & Lyons, 2008). The methodological devices include tools such as workshops, analysis grids, questionnaires, and IT tools (Boons & Howard-Grenville, 2009) and often rely on the presence of a facilitator to promote inter-firm exchanges and ensure the sustainability of ITE projects.

Inter-firm relations and proximity links, of various kinds, are considered particularly important in ITE or CE processes at the local level (Cerceau et al., 2018). Indeed, it is not only a matter of firms' location within the same area and of functional and productive relationships within a local system, but also of collaborative exchanges between firms, based on their potential similarities and shared interests. While the literature has extensively addressed these issues in the context of the linear economy, few articles approach them from the perspective of the CE. However, the latter, by its very nature, could potentially alter the way people collaborate (Niang et al., 2022).

The proximity approach has often been used to analyze relationships within local production or innovation systems (Torre & Gallaud, 2022). It also aims to understand the development of methodological devices used to contribute to the development of ITE. Its use allows for the isolation of the spatial, organizational, and institutional components of these relations and the study of their evolutions. According to the literature, proximity can be categorized into two main types: geographical and organized. Geographical proximity refers to the spatial closeness between two entities and can be perceived as either imposed or chosen. Unwanted geographical proximity involves circumstances where entities have no choice but to be near each other, either permanently (e.g., due to physical attributes of the location) or temporarily (e.g., due to short-term events or conditions). Conversely, sought-after geographical proximity is a deliberate positioning choice driven by perceived benefits of co-location. This chosen proximity can also be permanent (e.g., choosing to set up a business in a specific location due to its advantageous conditions) or temporary (e.g., choosing to attend a conference or a meeting in a specific location). Organized proximity, on the other hand, refers to relationships that are independent of geographical distance. This type of proximity is built around the logic of belonging and similarity. The logic of belonging refers to relationships formed based on common membership in a group or organization, while the logic of similarity involves relationships formed due to shared characteristics or interests (Torre, 2011).

This study aims to investigate the effectiveness of methodological devices in creating a conducive environment for the implementation of ITE strategies. It specifically focuses on the role of intermediaries in this process and aims to fill the gap in understanding the modalities of implementing ITE strategies. The research question addressed is: How effectively do these tools promote inter-firm relations and facilitate the implementation of ITE approaches? The answer to this question must also allow us to clarify the validity of these devices, their ability to promote interactions, as well as their ability to generate permanent interactions. The work relies on the theoretical framework of proximities (Torre & Rallet, 2005) to understand the nature of inter-firm relationships and their evolution as ITE projects are deployed.

The paper provides empirical insights into the effectiveness of methodological devices (widely supported and encouraged by public actors) used to promote inter-firm relationships within ITE projects and highlights their local dimension. These insights have the potential to illuminate the practices that are most effective in fostering inter-firm collaboration for ITE projects, providing guidance for future initiatives and strategies. Additionally, this study contributes to the theoretical understanding of the role of proximity in these collaborations, specifically within the context of the ITE. This understanding can enhance the knowledge of the conditions under which inter-firm collaboration is likely to succeed, informing both theory and practice in the field of industrial ecology. This topic is crucial as industrial ecology can be viewed as a catalyst for achieving sustainable

development goals (Awan, 2022). Finally, this paper advances methodological approaches in the field through a combined use of interviews and social network analysis.

In the remainder of the paper, we provide an explanation of the analysis methodology, which is based on interviews and social network analysis conducted in three case studies. Subsequently, we present and discuss the main results. The concluding section of the article is dedicated to the conclusion and a reflection on the implications of the findings.

2 | METHODOLOGY

The analysis is based on a methodology that aims to highlight the structure of inter-firm relations and their evolution over time, as well as to evaluate the role played by proximity relations in this structuring and its evolution. The study and the visualization of the structure of the relationships are based on an approach in terms of social networks and proximities, carried out through directive and semi-directive interviews.

2.1 | Presentation of the case studies

The principles of the CE, key to Europe's reindustrialization efforts and environmental preservation, have been integrated into numerous public policies. The European Commission's circular economy action plan of March 2020, part of the Green Deal, epitomizes this commitment. Similarly, France has implemented measures for sustainable economic growth and decarbonization. ITE is one of the strategies promoted through CE public policies. This study focuses on three French regions using methodologies to foster local business collaboration and synergies on ITE issues.

Comparative case study approach was used due to its ability to consider contextual factors and practices (Stake, 2013), helping to understand tool effectiveness, specificities of each case and the common challenges in the ITE implementation strategies. The multiple case study approach adopted here consists in highlighting recurring phenomena among several situations by comparison, after observing and analyzing each situation for itself. It should be noted that each case has been studied in depth, not only by numerous interviews or discussions, but also by a very regular follow-up of meetings between actors. This method seems relevant to compare the way in which inter-firm relations emerge within these three case studies, each with its own methodological device. It allows detailed understanding of each case's specifics, facilitates identification of trends and good practices, tests management theories across contexts, and provides practical knowledge for real-world application (Stewart, 2012; Tharenou et al., 2007).

Methodological devices that have been compared involved:

- the organization of workshops to actively involve companies in synergy search, facilitating their engagement and adoption of the approach,
- the use of a software to ease data processing and identify industrial ecology synergies,
- the intervention of a third party that manage interfacing with companies to support synergy implementation and long-term networking.

2.1.1 | The NISP device in Nord Isère

Located in Rhône-Alpes, the Nord Isère territory comprises 232 municipalities, with an economy primarily focused on the tertiary sector. The methodological device analyzed here has been developed by the British consultancy International Synergie, inspiring from methods and tools used by the National Industrial Symbiosis Program in UK (NISP²). The device uses workshops to facilitate synergy identification based on company needs. Companies formulate their needs (in the form of "I have" and "I want" this or that resource) and potential synergies are identified in the form of an auction. Each company can position itself on the flows that interest them. After the workshop, the tool SYNERGie aids in synergy identification and management. Thirty-nine companies have been involved in this device, mainly from the region's north and adjacent departments.

The area's extensive road network, including A43 and A7 highways, facilitates resource and personnel transport. Most firms are located near these roads, while others are scattered across the experimental area. The average distance between participating companies is 54 km, and the average travel time is under 45 min.

2.1.2 | The INEX device in Drôme-Ardèche

The Drôme-Ardèche region consists of 127 municipalities. Despite a declining industrial sector, it still accounts for 22% of jobs, with the tertiary sector at 64%, construction at 10%, and agriculture at 4%. The dominant chemical industry is moving toward sustainable solutions like "green" chemistry and industrial ecology due to global market influences and societal pressures.

The INEX methodological device has been created by a French private consultancy. It also uses a dedicated software whose functions are different from those of NISP. Companies convene at workshops, grouped by pre-identified needs-based themes by the software. And after the workshop, companies can continue to discuss the implementation of synergies using the software, via a collaborative platform. Thirty-two companies from diverse sectors have been involved in this methodological device.

The experiment's target area features a robust road infrastructure along the Rhône, including national road 7 and the A7 highway. Over 20 companies are near this Vienne to Valence axis, with others scattered throughout the territory. The average distance between workshop companies is 38 km, and the average travel time is under 32 min.

2.1.3 | The CCI Quimper Cornouaille device

Concarneau Cornouaille Agglomeration is a group of nine municipalities in Southwest Brittany. The region has a significant service sector (48%) and trade (28%), but it remains highly industrialized, with the food industry accounting for nearly half of the industrial jobs. Notably, its seven fishing ports constitute 24% of French freshwater fishing.

The Quimper Cornouaille (QC) Chamber of Commerce and Industry developed a methodological device based on the software ACTIF and the NISP approach. ACTIF helps to identify industrial ecology synergies from data (input and output of companies) that have to be collected previously. But to avoid that first step and reduce data collection time, a workshop of NISP device has been organized. Eighteen varied-sector companies have been involved in this methodological device, half coming from the nautical and fishing sectors.

Nearly half of the companies are located in the Concarneau port area, a small portion in the city center, and the rest are located on the outskirts of the city in the business parks, with the exception of two companies that are slightly further away (the furthest one being located at 7 km). The locations are very close: the average distance between the companies present at the workshop is 3 km, and can be reached in a few minutes on foot or by car.

2.2 | Networks and proximities data collection

The methodological framework is conceived for exploring the role of proximity in facilitating or inhibiting interactions, collaboration, and knowledge sharing in diverse fields and contexts. This analytical lens also provides an opportunity to identify potential changes and evolutions in the nature and the position of local actors, in particular the intermediaries.

2.2.1 | Directional and semi-structured interviews

The study included 74 in-depth interviews with a specific group of companies and intermediary entities (such as facilitators, funders, and coordinators) involved in ITE projects in three French regions. The purposive sampling method focused on 55 companies and 7 "solutions carrier" structures (mostly waste management companies), selected for their varied sizes, industry sectors, and roles in the ITE projects.

Interviews were conducted 10–15 months post inter-company workshops, allowing enough time for project progression and results. This mixed-method approach incorporated directive and semi-directive interviews for specific information and open-ended responses, respectively.

The directive interviews, using sociometric questions with preset answers, collected information on social network analysis. Each company provided insights on their relationships with other participating companies, based on criteria such as interactivity, synergy establishment, and perceived geographical distances. The interviews concluded with open-ended questions on the company's motivation, expectation fulfilment, and overall opinion on the process.

Interviews, lasting 15 min to 1 h, were mostly conducted over the phone with some face-to-face. The interviewees held management roles or responsibilities in purchasing, environment, and safety. Representatives of the "solutions carrier" organizations also completed the questionnaire.

The semi-structured interviews, varying from 26 min to over an hour, gathered contextual information. These were conducted with "solutions carrier" structures, which provided an overview of the project's evolution (Table 1). The main question was their reasons and methods of participation in the process. The discussion was then focused on interactions, actions, controversies, and key events or facts see [Supporting](#).

2.2.2 | Coding inter-company relationships to reconstruct networks and their evolution

The interview data was analyzed to reconstruct actor networks and their evolution, with a focus on inter-firm relationships. For each case study, a diachronic network analysis was conducted, allowing for the visualization of the network before, during, and after the workshop. The data was organized into matrices, with certain relationships being considered reciprocal (symmetrical) to indicate two-way interactions. These reciprocal relationships included the origin of the relationship, the use of parallel networks, and collaborations outside of the ITE project.

TABLE 1 Summary of case study data collection techniques.

Case studies	Networks and proximities	Proximities	Documents	Observations
Nord Isère	- 22 companies - 2 coordinators (CCI Nord Isère and Grenoble) - 1 funder (ADEME)	- 1 leader (Institute of Circular Economy) - 1 coordinator (CCI Nord Isère) - 1 funder (ADEME)	Meeting and workshop reports; press articles; websites of CCI Nord Isère; Scot du Nord Isère	Workshops; training sessions; project follow-up meetings
Porte de Drôme-Ardèche	- 19 companies - 1 coordinator (INex)	- 1 coordinator (INex) - 1 funder (GPRA)	Workshop and meeting reports; press articles; websites of CCPDA and GPRM; Scot des Rives du Rhône	Workshops
Cornouaille	- 14 companies - 1 coordinator (CCI QC)	- 1 CCI QC (Coordinator and Leader) - 1 CCA (Leader)	Meeting reports; press articles; websites of CCI QC and CCA; master's thesis	Field visits, no observation of workshops

Some variables were non-reciprocal and related to each actor's perception, such as geographical distance, familiarity with a person or company, the intensity of the relationship over time, and the perception of the relationship's personal nature. Social network analysis was employed on these matrices to measure the overall structure of the network (density and number of relations) and actor centrality, which indicates their importance. The four common centrality indicators used were degree, closeness, betweenness, and eigenvector centralities. By comparing these indicators over time, it was possible to identify changes in the network structure, subsets within the network, and the most central actors.

2.2.3 | Proximity indicators

The theoretical framework of proximities (Torre & Rallet, 2005) is used for this analysis. This framework examines how the dimensions of proximity influence interactions and relationships, particularly within the context of localized economies and innovation. The research on clusters, which are localized groupings of firms, and local systems of innovation has primarily focused on the role of geographical proximity in fostering cooperative relations between firms (Aguilera et al., 2012; Crevoisier, 2004; Arfaoui et al., 2024; Scott, 1986; Thierstein et al., 2008). Successful exchange or cooperation depends not only on proximity but also on commonalities, such as technological or sectoral similarity, complementarity, organizational modes, or shared cultures. From this perspective, Bourdin and Torre (2024) are talking about "territorial circular ecosystem."

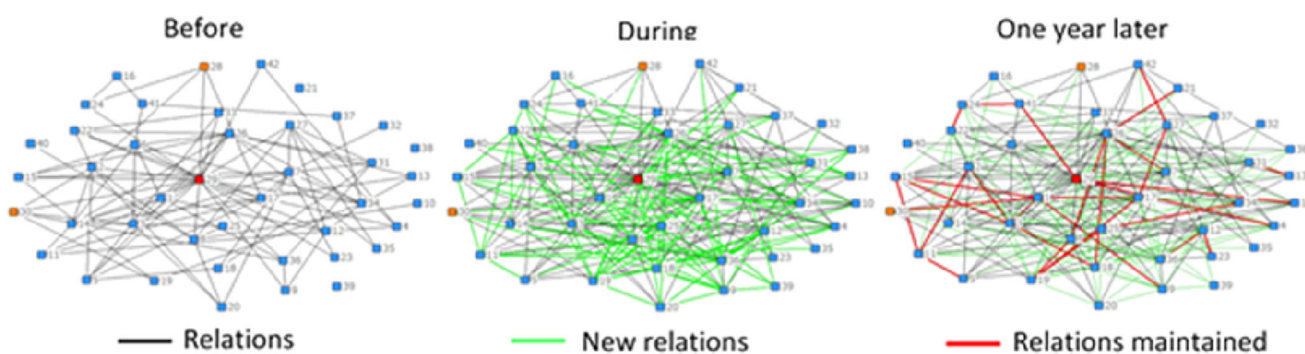
However, current research indicates a need for more dynamic approaches to understand not only the role of these proximity but also their interplay and mutual influences (Balland et al., 2015). This includes consideration of different proximities over time, alternating phases of temporary geographical proximity and organized proximity at a distance (Torre, 2011). Spatial dimension is also at the heart of ITE, requiring geographically close firms for efficient exchange of material and energy flows (Chertow, 2007; Bourdin et Torre, 2024; Torre & Dermine-Brulot, 2021). This also means considering the specific features of the territory, both in terms of issues to address and resources available to solve them (Korhonen et al., 2018).

After capturing the network structure and the set of inter-firm relationships through social network analysis, an analysis in terms of proximities was conducted. The contributions by Knobens and Oerlemans (2006), Boschma (2005), and Torre and Rallet (2005) propose typologies of proximities that influence local systems. This approach provides elements for understanding the logic underlying the relationships and their evolution. The information necessary for this stage is obtained from the additional information provided in the sociometric questionnaire, but also from the semi-structured interview. The purpose of this triangulation is to cross-check the information in order to avoid interpretation bias linked to each source (Hussein, 2009). To assess the role of geographical and organized proximity in inter-firm relationships, we employed specific metrics to empirically illustrate the degree to which both proximities shaped collaboration within the territorial context. For geographical proximity, the metric used was the physical distance between firms, measured in kilometers, which allowed us to evaluate how spatial closeness influenced the formation of relationships. In terms of organized proximity, we analyzed the number of relationships established versus the number of possible relationships within the network, capturing the extent to which shared values and goals activated cooperation.

To characterize inter-firm relations, specific dimensions of proximity were examined: permanent and temporary geographical proximities, in addition to the logics of belonging and similarity within organized proximity (Table 2). This proximity-centered analysis was implemented across the three main phases of the initiatives (pre-, during, and post-workshop). This methodology enables the depiction of the evolution of proximities—their emergence, progression, decline, or cessation—and offers valuable perspectives on the mechanisms of their formation and dismantling. A thematic analysis, integrating chronicle, social network analysis, and proximity categories, was deployed to attain these insights.

TABLE 2 The different categories of proximity used in the study.

Proximities			Indicators
Geographical	Sought for	Permanent	Corresponds to a location deemed appropriate
		Temporary	Is satisfied without change of location, via mobility or occasional trips of more or less long duration.
	Unwanted	Permanent	Corresponds to the situation of actors who are imposed permanently or temporarily the geographical proximity of people, activities, technical objects, or places.
		Temporary	
Organized	Logic of belonging	Refers to interactions between actors facilitated by belonging to the same organization or network and which share a number of rules and behavioral routines.	
	Logic of similarity	Corresponds to mental and cognitive adherence to common categories. It can facilitate interactions between people who adhere to similar references, who share similar values or cultures, or social norms	

**FIGURE 1** The inter-firm network before, during, and after the National Industrial Symbiosis Program workshop.

3 | RESULTS

We underscore the influence of proximities, be there geographical or organized ones, and of intermediation behaviors on the inter-firm relationship dynamics. The analytical categories of network and proximity provide a comprehensive perspective on the evolution of relationships in the three case studies.

3.1 | The evolution of networks and proximities

3.1.1 | The NISP device in Nord Isère: A little mobilized geographical proximity

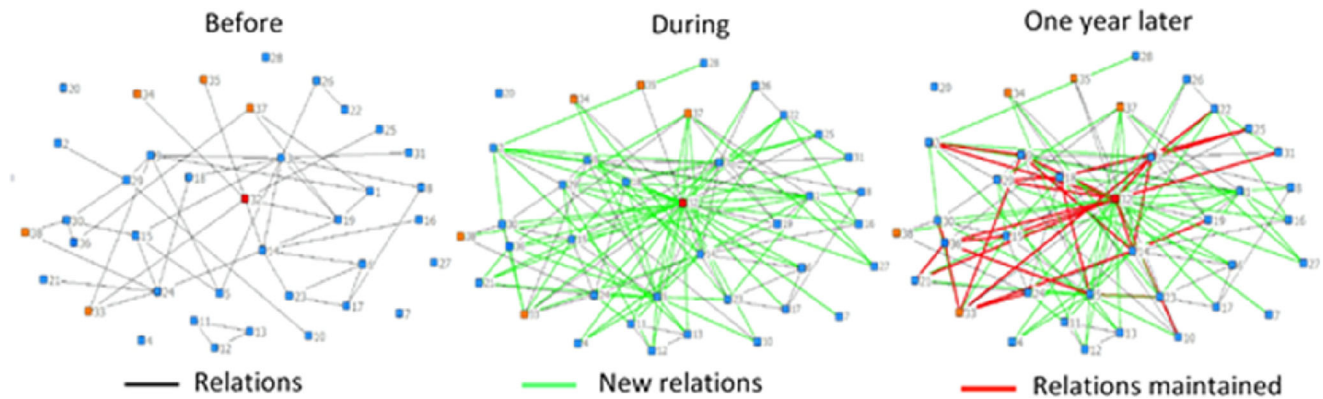
Prior to the implementation of the methodological device, and particularly before the workshop, the network comprising 39 business entities displayed a rather diffuse structure, with a total of only 125 relationships (see Figure 1). The program's facilitator assumed a crucial intermediation role, exercising significant influence over a portion of the interactions. However, subsequent to the workshop, which emphasized face-to-face interactions, the network's density notably increased, almost doubling the number of relationships. This moment of temporary geographical proximity led to a reduction in the facilitator's central role. Despite these advancements, only 31 out of the 221 relationships established during the workshop endured after 1 year, indicating a relatively low retention rate.

In terms of organized proximity, all participating companies shared a degree of similarity, particularly around environmental values, but only a handful activated these shared values in the context of inter-company exchanges related to the ITE project. Geographical proximity also played a role (Table 3), with an average travel time of less than 45 min between companies, although the perceived distance depended on contextual factors, such as firm size and location.

The NISP workshop fostered temporary geographical proximity, creating a platform for interactions between distant companies and reinforcing ties between geographically close ones. However, without sustained organized proximity—involving shared norms and values—these relationships

TABLE 3 Number of relations related to the road distance in the National Industrial Symbiosis Program device study.

Distance (km)	Number of observed relations	Number of possible relations	Relation between observed and possible (%)
<20	36	127	28
20–50	59	316	18
50–100	24	332	7
>100	6	83	7

**FIGURE 2** The inter-firm network before, during, and after the INex workshop.

did not last. The absence of follow-up meetings and the varying levels of post-workshop support weakened the retention of the values and collective learning initiated by the process.

The NISP workshop served as a moment of temporary geographical proximity, providing a platform for face-to-face interactions. It facilitated the establishment of relationships between geographically “distant” companies and allowed those in close proximity but unfamiliar with each other to leverage their geographical proximity. Furthermore, the workshop set the stage for a new form of organized proximity, fostering shared language, concepts, and values related to ITE. This played into the similarity logic that companies held in terms of environmental values.

However, this interactive momentum was not sustained in the medium term, and the organized proximity thus created was rarely preserved. The lack of subsequent meetings proved detrimental, and the support given post-workshop varied greatly from company to company. To embed the values, norms, and representations initiated by the process centrally, a collective learning process beyond what was included in the original methodology was necessary. In the end, the norms and standards were more easily disseminated through new relationships established during the workshop rather than between companies that had already established their own system of standards.

3.1.2 | The INEX device in Drôme–Ardèche: A weakness of organized proximities

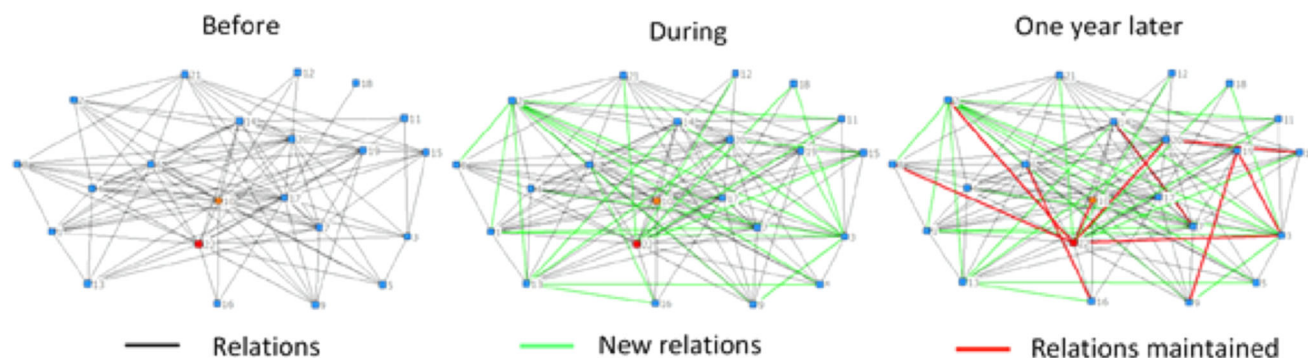
Initially, there were 32 companies in a network that was rather sparse, having only 49 relationships among them (Figure 2). Many of these interactions were collaborations of varying natures. The facilitator did not play a significant role in the network at this stage. However, during the workshop, the dynamics changed significantly. The density of the network increased, and the number of relationships almost tripled. This transformation made the facilitator become a vital intermediary in the network.

One year after the workshop, 29 out of the newly created 131 relationships survived. Notably, the facilitator was involved in about half of these surviving relationships. It is essential to mention that not all participants received support after the workshop, and this was partly due to the absence of a formal contract between the facilitator and the project leader.

In terms of proximity, before the project implementation, the companies barely knew each other and had very few interactions. They were distributed across five different French departments, and their potential for coordination was limited. Despite sharing values around circular economy practices, the diversity of sectors represented, and the diverse roles of the company representatives, suggest that the adoption of similar values was not a straightforward process.

TABLE 4 Number of relations related to the distance (km) in the INEX device study.

Distance (km)	Number of observed relations	Number of possible relations	Relation between observed and possible (%)
<20	19	140	13
20–50	12	294	4
50–100	10	178	5.6
>100	1	91	1

**FIGURE 3** The inter-firm network before, during, and after the CCI workshop.

In estimating geographical proximity, participants across the board considered companies within a range of 20 to 40 km as “close” (Table 4). This perception was consistent regardless of the size of the companies. The workshop succeeded in creating a temporary geographical closeness, leading many participants to realize the potential of their existing geographical proximity.

The workshop encouraged the development of new organized connections, based on the shared values of ITE and closely linked to the specific territorial contexts of the participating firms. The facilitator served as a vital intermediary, aligning the improvement of local resources with the promotion of cost-effective production and long-term territorial dynamics. This territorial integration facilitated the establishment of relationships between companies with limited prior interactions, emphasizing the significance of localized cooperation for ITE projects.

However, the energy created during the workshop dwindled significantly over time, with most relationships not extending beyond the immediate post-workshop phase. Companies that sustained connections were typically located within a 41 km radius, highlighting the ongoing importance of geographical proximity in maintaining inter-firm relations. In contrast, companies situated farther away struggled to uphold these connections. This situation indicates that the territorial reach of the workshop significantly affected the sustainability of the relationships.

The absence of follow-up meetings and ongoing mediation—determinant for strengthening the organized connections formed during the workshop—contributed to the breakdown of relationships over time. Although a virtual collaborative platform was introduced to address the challenges of geographical distance, it was underutilized due to concerns about increased workload. Consequently, the enduring relationships were primarily within the Drôme–Ardèche local authority, reflecting a strong sense of regional identity and a shared understanding of local dynamics. This feeling of belonging was initially nurtured by the intermediary but lacked long-term support. This situation underscores the necessity for continuous territorial engagement to preserve relationships established through ITE initiatives.

3.1.3 | The CCI Quimper Cornouaille device: Strong organized proximities

Before the process, the network of 20 companies was very dense, with 108 relationships (Figure 3). Three actors (including the project leader) were a little more central than the others, but there was a certain homogeneity in terms of centralities. During the workshop the network became slightly denser, with the formation of 26 new relationships, its homogeneity was strengthened and the facilitator, the Chamber of Commerce and Industry (CCI) Quimper Cornouaille, became the central intermediate actor. One year after the workshop, only 10 out of 134 relationships were maintained, half of which involved the CCI. This can be explained by the lack of follow-up by the facilitator and by the inadequacy of the methodological framework to facilitate the coordination of actors.

The large number of relationships maintained prior to the approach reveals the existence of organized proximities between the companies. The frequentation of the same networks and the pre-existing collaborations illustrate a logic of belonging in the inter-firm interactions. The strong permanent geographical proximity between the companies is regularly activated through events organized within the port of Concarneau (mainly

linked to boating and fishing), meetings between local elected representatives and companies, or during meetings specific to each inter-firm network. Crossing paths in various networks, companies end up sharing a certain number of common rules and behaviors, hence the importance of the logic of similarity. Moreover, these networks are all linked to marine activities (boating and fishing); the companies, which interact a lot, belong to complementary sectors, located within this field.

Regarding the assessment of geographical proximity, all companies participating in the workshop perceived themselves as being close to each other. This perception is largely due to the fact that most are located within a 3 km radius. The workshop served to further enhance this sense of geographical closeness, as evidenced by the fact that the average distance between companies forming new relationships decreased to 2 km. However, it is important to note that pre-existing organized proximities among the companies—those based on prior inter-company relations—ultimately hindered the development of new organized proximities that the workshop attempted to foster. Despite a unifying discourse centered on economic gain and competitiveness, the workshop alone was insufficient to cultivate a new organized proximity that encompasses a shared understanding of ITE issues.

3.2 | Proximities and the active role of local intermediaries

The findings derived from the three case studies underscore the significance of proximities, encompassing both geographical and organized dimensions, in influencing the development of inter-firm relationships. While permanent geographical proximity played a crucial role in maintaining cooperative ties, it alone did not suffice for their establishment. Across all three cases, intermediaries, especially facilitators, emerged as pivotal in activating these proximities, especially organized ones. Methodological tools, such as workshops and interactive platforms, facilitated the creation of temporary geographical and organized proximities by fostering trust, shared norms, and collective learning.

Nevertheless, the endurance of these relationships hinged significantly on the post-workshop follow-up and support provided. In instances where organized proximity, characterized by shared norms, values, and objectives, was not reinforced, relationships tended to deteriorate over time, irrespective of geographical proximity. These results underline the necessity for ongoing intermediation and consistent interaction to ensure that the initial impetus generated by the workshops translates into enduring collaboration.

3.2.1 | Permanent geographical proximity contributes to the maintenance of cooperative relationships, but it is not sufficient for their establishment

The literature in regional science has largely demonstrated the importance of permanent geographical proximity to facilitate collaborations in linear economy models (Torre & Gallaud, 2022). This paper suggests that this dimension is also crucial in circular economy models. This research shows that the relationships between participants tend to decrease the further away the firms feel from each other. Indeed, the further apart firms are, or perceive themselves to be, the less they maintain the links created during the workshops. Also, although the firms are usually located in a fairly tight geographical area, it can be observed that geographical proximity is not sufficient to bring about cooperative relationships. Indeed, companies do not always share the same objectives, they have not necessarily met in professional or personal networks, and finally they can live side by side while completely ignoring each other. In a word, they do not share organized proximities.

3.2.2 | There is a need for intermediary actors and methodological devices to activate organized proximities

Literature suggests that shared values or interests among groups can promote the formation of collaborative networks (Boons & Baas, 1997; Boschma et al., 2005; Torre & Rallet, 2005). However, although these commonalities partly existed in two of the three case studies, they were not the primary factor for establishing robust connections. This result partly undermines the studies on cooperation, which tend to demonstrate the positive influence of past collaborations and collective social capital in the establishment of new relationships. In these case studies, when companies already knew each other before the workshop, it was more difficult to create new relationships in connection with ITE. The workshop developed a common, shared frame of reference around ITE and its challenges. New relationships built during the workshop are based on this frame of reference, and lead more easily to the implementation of ITE synergies.

The role of intermediaries or institutional appears critical. Facilitators, especially, play a pivotal role in activating these potential proximities through specific actions (Bourdin & Nadou, 2020; Patala et al., 2020; Schlüter et al., 2022). In all these case studies, they were essential not just for enabling, but initiating inter-firm relationships. Methodological devices, such as methods used during the workshops to share information and knowledge between companies, helped build these connections around shared concerns. However, the successful application of these tools depends on the presence of a facilitator, whose role is to create a “climate of trust” conducive to the development of a shared vision in relation to ITE. Trust is often mentioned as essential in literature on industrial ecology (Ashton and Bain, 2012; Hewes & Lyons, 2008), but often in a rather

naïve way, like it was possible to build it rapidly and to rely on it easily. But the literature on trust reveals that it is a long process to be built through numerous and very active interactions, through time, and that it has to be nurtured by permanent and repeated interactions (Dupuy & Torre, 2006; Nooteboom, 2002), which is obviously not the case in these studies. At best, the involvement of intermediary actors is conducive to stronger interactions. The research protocol developed in this article does not really measure interpersonal trust between actors, but rather the creation of a climate (of trust) conducive to the emergence of collective action, through the intermediary of the facilitator and thanks to the methodological devices within the framework of which the facilitator accompanies the actors in the process.

3.2.3 | ITE relationships are built, but they do not last if they are not nurtured

The many relationships that have been developed around the interactive workshops have, on the whole, survived little over time. This finding, which is less true in CCI Quimper Cornouaille case study, clearly shows that the relationships established cannot be sustained over the long term without effective and repeated support (Torre, 2011). However, while the facilitators were very effective in recruiting companies or creating links during the workshops, they did not, on the whole, provide very effective or repeated follow-up. The provision of a platform for interaction did not prove sufficient either, in the absence of external incentives or solicitations to maintain interaction. For example, even if the collaborative platform proposed by INEX is declared as interesting by firms, using it takes too much time. This is in line with the results already established by Polge and Torre (2018) in the case of territorial governance arrangements in linear economy in Northern Brazil. Relationships between local enterprises had developed as long as the mechanisms for linking actors remained active, but then rapidly declined following the disappearance of the latter and the action of their facilitators. Thus, we arrive at the same conclusions as the literature studying linear economy models, namely that collective learning takes time and requires regular interactions between stakeholders (e.g., through the organization of recurrent events—temporary geographical proximity) to maintain and increase inter-firm collaborations (Torre, 2011). From this point of view, the present results highlight the relation between the persistence of interactions and the role of intermediary actors.

4 | CONCLUSIONS

This article analyzed how inter-firm relationships are constructed and maintained over time in the context of circular economy, specifically in ITE projects utilizing intermediation tools. The findings demonstrate that while geographical proximity is necessary, it is insufficient alone for the successful implementation of ITE projects. The role of methodological devices was crucial in fostering and maintaining these inter-firm collaborations. However, sharing common values and ambitions did not always facilitate cooperation, which required regular meetings and ongoing support to sustain.

The study also highlighted the significant role of intermediary actors in building, maintaining, and expanding inter-firm relationships. Furthermore, the importance of time in collective learning and creating mutual relationships in ITE was emphasized. This research underscores the need for consistent and effective support to ensure the longevity and success of ITE projects.

In light of previous work on ITE in France, notably the feedback provided by ORÉE³ over the past 15 years, our findings align with ongoing discussions about the sustainability of these initiatives. Our research contributes to these discussions by pointing out that, beyond the initial phases of public funding, ensuring the long-term role of facilitators or intermediaries becomes increasingly crucial. This concern is also evident in ADEME's latest report (2024),⁴ which shifts the focus from the sustainability of firm relationships to the institutional and financial arrangements necessary to maintain these initiatives over time. This consideration prompts further examination of how to support the role of intermediaries after the typical project funding, often limited to 2 or 3 years, ends. Exploring hybrid funding models that combine public and private resources would be a new step in ensuring the ongoing facilitation of these collaborations. Potential approaches may involve incorporating this responsibility into existing structures, like local chambers of commerce or regional governments, where it could be linked to economic development or environmental services. Alternatively, creating ad hoc structures, such as local NGOs or Sociétés Coopératives d'Intérêt Collectif (SCICs), could also provide a more flexible model.

The findings of this study on inter-firm relationships within CE initiatives, particularly in ITE projects, also align with and expand upon existing literature on IS from various global contexts. For instance, research from the Kalundborg Eco-Industrial Park in Denmark highlights the critical role of geographical proximity and intermediary actors in facilitating resource exchanges and maintaining long-term collaborations (Jacobsen, 2006). Similarly, studies from China's National Eco-Industrial Parks have demonstrated that while initial proximity and shared environmental goals are essential, the sustained success of IS projects depends on continuous support and effective facilitation by local authorities and intermediary organizations (Geng et al., 2009). In South Korea's Ulsan Eco-Industrial Park, regular meetings and methodological tools were found to be vital in fostering cooperation, similar to our findings (Behera et al., 2012). However, unlike some global examples where cultural and institutional similarities significantly eased collaboration (Chertow, 2007), our study suggests that even with shared values and ambitions, additional structured interactions are necessary to overcome potential cooperation barriers. These comparisons stress that while local engagement and methodological facilitation

are universally critical, the specific dynamics and requirements for sustaining IS collaborations can vary significantly based on regional and cultural contexts.

In this sense, these results lead to several recommendations for policymakers and practitioners in the CE field. First, these findings underscore the importance of anchoring CE approaches at the local level to leverage their environmental and organizational benefits. This implies that local policymakers should prioritize creating conducive environments for CE initiatives by understanding and aligning with the specific needs and capabilities of local businesses. Second, to foster long-term relationships and cooperation between local businesses, there is a clear need for well-structured, methodological devices that facilitate regular and meaningful interactions. Such devices should be versatile and adaptable to the specific context of the localities they are deployed in. Intermediary actors, such as facilitators or local development agencies, are crucial in this process. They act as bridges between firms, helping to translate the overarching goals of the CE into actionable and mutually beneficial collaborations. Local authorities, due to their in-depth knowledge of the local economic landscape and proximity to regional businesses, are well-positioned to play a more strategic role. They can help in identifying and bringing together diverse stakeholders, facilitating the exchange of knowledge, and fostering a collaborative culture. However, for the sustainability of such relationships, it is not enough to initiate interactions; there is the need for an ongoing support. Therefore, local authorities should consider dedicating resources, both human and financial, to the long-term management and nurturing of these collaborative networks. This includes providing platforms for continuous dialogue, recognizing and incentivizing sustainable practices, and monitoring the progress and impact of collaborative initiatives.

While this study provides meaningful insights for deploying CE projects, its limitations must be acknowledged. The research was based on a relatively small sample of case studies situated in France, which may not necessarily represent other geographical contexts or industrial sectors. Additionally, the study relied on self-reported data from the participants. This approach, although valuable for gaining first-hand insights, is potentially subject to social desirability bias or other forms of response bias. The participants might provide overly positive accounts of their experiences and roles within ITE projects, thus skewing the results. Recognizing these limitations helps guide the direction of future research, potentially advocating for larger, more diverse sample sizes and further validation of self-reported data. Expanding the scope of research geographically and across different industrial sectors would allow for a richer understanding of the effectiveness of methodological systems in various contexts. Comparative studies involving ITE projects from diverse regions and sectors could shed light on the versatility and adaptability of these systems. Finally, a longitudinal study design, following ITE projects over time, would provide valuable insights into the long-term sustainability of these projects and the durability of inter-firm relations fostered by these methodological devices promoted by policymakers.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available upon reasonable request.

ORCID

Sébastien Bourdin  <https://orcid.org/0000-0001-7669-705X>

ENDNOTES

¹ The Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME), created in 1991, is a French industrial and commercial public institution involved in the implementation of public policies in the fields of the environment, energy and sustainable development: <https://www.ademe.fr/en/frontpage/>

² NISP is a recognized methodology developed by British consultancy International Synergies, primarily aimed at facilitating sustainable business practices by promoting industrial symbiosis. Industrial symbiosis involves diverse organizations working together to improve resource efficiency and reduce environmental impact through the shared use of materials, energy, water, and assets. By encouraging firms to collaborate, NISP fosters the exchange of resources among industries, thereby contributing to circular economy objectives by reducing waste, sharing resources, and creating more sustainable production cycles. <https://www.nispnetwork.com/>

³ <http://www.oree.org/index.html>

⁴ <https://www.actu-environnement.com/media/pdf/news-44913-rapport-ademe-economie-industrielle-territoriale.pdf>

REFERENCES

- Aguiléra, A., Lethiais, V., & Rallet, A. (2012). Spatial and non-spatial proximities in inter-firm relations: An empirical analysis. *Industry and Innovation*, 19(3), 187–202.
- Arfaoui, N., Bourdin, S., Torre, A., Vernier, M. F., & Vo, L. C. (2024). Geographical and organised proximities influencing circular economy practices: the closer partners, the better? *Regional Studies*, 58(12), 2485–2500.
- Awan, U. (2022). Industrial ecology in support of sustainable development goals. In *Responsible consumption and production* (pp. 370–380). Springer International Publishing.
- Balland, P. A., Boschma, R., & Frenken, K. (2015). Proximity and innovation: From statics to dynamics. *Regional Studies*, 49, 907–920.
- Beaurain, C., & Brullot, S. (2011). L'écologie industrielle comme processus de développement territorial: Une lecture par la proximité. *Revue d'Economie Régionale et Urbaine*, 313–340.

- Behera, S. K., Kim, J. H., Lee, S. Y., Suh, S., & Park, H. S. (2012). Evolution of 'designed' industrial symbiosis networks in the Ulsan Eco-industrial Park: 'Research and development into business' as the enabling framework. *Journal of Cleaner Production*, 29–30, 103–112.
- Belaud, J. P., Adoue, C., Vialle, C., Chorro, A., & Sablayrolles, C. (2019). A circular economy and industrial ecology toolbox for developing an eco-industrial park: Perspectives from French policy. *Clean Technologies and Environmental Policy*, 21, 967–985.
- Boons, F. A., & Baas, L. W. (1997). Types of industrial ecology: The problem of coordination. *Journal of Cleaner Production*, 5(1–2), 79–86.
- F. Boons, & J. A. Howard-Grenville (Eds.). (2009). *The social embeddedness of industrial ecology*. Edward Elgar Publishing.
- Boschma, R. (2005). Proximity and innovation: A critical assessment. *Regional Studies*, 39, 61–74.
- Boschma, R. A. (2005). Does geographical proximity favour innovation? *Économie et institutions*, (6–7), 111–128.
- Boulding, K. (1966). The economics of the coming Spaceship Earth. In *Environmental quality in a growing economy*. Resources for the Future, Inc.
- Bourdin, S., Galliano, D., & Gonçalves, A. (2022). Circularities in territories: Opportunities & challenges. *European Planning Studies*, 30(7), 1183–1191.
- Bourdin, S., & Nadou, F. (2020). The role of a local authority as a stakeholder encouraging the development of biogas: A study on territorial intermediation. *Journal of Environmental Management*, 258, 110009.
- Bourdin, S., & Torre, A. (2020). The circular economy as a means of territorialisation of European industry. *Symphony Emerging Issues in Management*, (2), 33–40.
- Bourdin, S., & Torre, A. (2024). Economic geography's contribution in understanding circular economy. *Journal of Economic Geography*, Ibae040.
- Brulot, S. (2009). *Mise en œuvre de projets territoriaux d'écologie industrielle en France: Vers un outil méthodologique d'aide à la décision*. Thèse de doctorat en aménagement, Université de Technologie de Troyes.
- Brulot, S., Maillfert, M., & Joubert, J. (2014). Stratégies d'acteurs et gouvernance des démarches d'écologie industrielle et territoriale. *Développement durable et territoires*, 5(1).
- Buclet, N. (2021). *Territorial ecology and socio-ecological transition*. Wiley ISTE.
- Cerceau, J., Mat, N., & Junqua, G. (2018). Territorial embeddedness of natural resource management: A perspective through the implementation of industrial ecology. *Geoforum*, 89, 29–42.
- Chertow, M. R. (2007). Uncovering industrial symbiosis. *Journal of Industrial Ecology*, 11(1), 11–30.
- Crevoisier, O. (2004). The innovative milieus approach: Toward a territorialized understanding of the economy?. *Economic Geography*, 80(4), 367–379.
- Dupuy, C., & Torre, A. (2006). Local clusters, trust, confidence and proximity. In C. Pitelis, R. Sugden, & J. Wilson (Eds.), *Clusters and globalisation: The development of urban and regional economies* (p. 195) Edward Elgar.
- Frosch, R. A., & Gallopoulos, N. E. (1989). Strategies for manufacturing. *Scientific American*, 261(3), 144–153.
- Gallego-Bono, J. R., & Tapia-Baranda, M. (2022). Industrial ecology and sustainable change: Inertia and transformation in Mexican agro-industrial sugarcane clusters. *European Planning Studies*, 30(7), 1271–1291.
- Geng, Y., Zhang, P., Cote, R., & Qi, Y. (2009). Evaluating the economic and environmental benefits of an eco-industrial park in China. *Journal of Cleaner Production*, 17(8), 681–689.
- Hachaichi, M., & Bourdin, S. (2023). Wheels within wheels: Mapping the genealogy of circular economy using machine learning. *Circular Economy and Sustainability*, 3, 1–21.
- Hewes, A. K., & Lyons, D. I. (2008). The humanistic side of eco-industrial parks: Champions and the role of trust. *Regional Studies*, 42(10), 1329–1342.
- Hussein, A. (2009). The use of triangulation in social sciences research: Can qualitative and quantitative methods be combined?. *Journal of Comparative Social Work*, 4(1), 106–117.
- Jacobsen, N. B. (2006). Industrial symbiosis in Kalundborg, Denmark: A quantitative assessment of economic and environmental aspects. *Journal of Industrial Ecology*, 10(1–2), 239–255.
- Jambou, M., Torre, A., Dermine-Brulot, S., & Bourdin, S. (2022). Inter-firm cooperation and local industrial ecology processes: Evidence from three French case studies. *The Annals of Regional Science*, 68(2), 331–358.
- Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232.
- Knoben, J., & Oerlemans, L. A. G. (2006). Proximity and inter-organizational collaboration: A literature review. *International Journal of Management Reviews*, 8, 71–89.
- Korhonen, J. (2001). Regional industrial ecology: Examples from regional economic systems of forest industry and energy supply in Finland. *Journal of Environmental Management*, 63(4), 367–375.
- Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, 175, 544–552.
- Lewandowski, M. (2016). Designing the business models for circular economy—Towards the conceptual framework. *Sustainability*, 8(1), 43.
- Maillfert, M., & Schalchli, P. (2010). *Pré-requis pour la construction d'une méthodologie pour l'implantation d'une démarche d'écologie industrielle à l'échelle d'un espace territorial*. In M. Maillfert, O. Petit, & S. Rousseau (Eds.), *Ressources, patrimoine, territoires et développement durable* (pp. 45–68). Peter Lang.
- Niang, A., Bourdin, S., & Torre, A. (2023). The geography of circular economy: Job creation, territorial embeddedness and local public policies. *Journal of Environmental Planning and Management*, 67, 1–16.
- Niang, A., Torre, A., & Bourdin, S. (2022). How do local actors coordinate to implement a successful biogas project? *Environmental Science & Policy*, 136, 337–347.
- Nooteboom, B. (2002). *Trust: Forms, foundations, functions, failures and figures* (p. 256). Edward Elgar.
- Patala, S., Salmi, A., & Bocken, N. (2020). Intermediation dilemmas in facilitated industrial symbiosis. *Journal of Cleaner Production*, 261, 121093.
- Polge, E., & Torre, A. (2018). Territorial governance and proximity dynamics. The case of two public policy arrangements in the Brazilian Amazon. *Papers in Regional Science*, 97(4), 909–930.
- Schlüter, L., Mortensen, L., Drustrup, R., Gjerding, A. N., Kørnøv, L., & Lyhne, I. (2022). Uncovering the role of the industrial symbiosis facilitator in literature and practice in Nordic countries: An action-skill framework. *Journal of Cleaner Production*, 379, 134652.
- Scott, A. J. (1986). Industrial organization and location: Division of labor, the firm, and spatial process. *Economic Geography*, 62, 215–231.
- Stake, R. E. (2013). *Multiple case study analysis*. Guilford Press.
- Stewart, J. (2012). Multiple-case study methods in governance-related research. *Public Management Review*, 14(1), 67–82.
- Sundaram, A. K., & Hansen, R. G. (2023). *Handbook of business and climate change*. Edward Elgar Publishing.
- Tharenou, P., Donohue, R., & Cooper, B. (2007). *Management research methods*. Cambridge University Press.

- Thierstein, A., Lüthi, S., Kruse, C., Gabi, S., & Glanzmann, L. (2008). Changing value chain of the Swiss knowledge economy: Spatial impact of intra-firm and inter-firm networks within the emerging mega-city region of Northern Switzerland. *Regional Studies*, 42(8), 1113–1131.
- Torre, A., & Gallaud, D. (Eds.). (2022). *Handbook of proximity relations*. Edward Elgar Publishing.
- Torre, A., & Dermine-Brullot, S. (2021). The circular economy, solution for a sustainable territorial development. *Indian Journal of Regional Science*, LIII, 1, 15–28.
- Torre, A. (2011). The role of proximity during long-distance collaborative projects. Temporary geographical proximity helps. *International Journal of Foresight and Innovation Policy*, 7(1–3), 213–230.
- Torre, A., & Rallet, A. (2005). Proximity and localization. *Regional studies*, 39(1), 47–59.
- Veyssi re, S., Laperche, B., & Blanquart, C. (2022). Territorial development process based on the circular economy: A systematic literature review. *European Planning Studies*, 30(7), 1192–1211.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Torre, A., Bourdin, S., Dermine-Brullot, S., & Jambou, M. (2024). Implementing industrial and territorial ecology: The role of proximity and intermediaries in three French case studies. *Journal of Industrial Ecology*, 1–13. <https://doi.org/10.1111/jiec.13598>