



Intermediation dilemmas in facilitated industrial symbiosis

Samuli Patala^{a,*}, Asta Salmi^b, Nancy Bocken^{c,d}

^a Aalto University, School of Business, Ekonominaukio 1, Espoo, Finland

^b University of Vaasa, School of Marketing and Communication, UCS, Kampusranta 9 C, 60320, Seinäjoki, Finland

^c Lund University, IIIIEE, Tegnérplatsen 4, 223 50, Lund, Sweden

^d Lappeenranta University of Technology, School of Business and Management, Skinnarilankatu 34, 53850, Lappeenranta, Finland

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ABSTRACT

Industrial symbiosis (IS) is a key paradigm for achieving circular economy among industrial firms. Achieving new IS projects often requires outside facilitation, and intermediaries can help solidify and expand existing IS networks. While various intermediary roles have been identified in the literature, less attention has been paid to the potential challenges that intermediaries might encounter in their activities. Based on the case of the national symbiosis network FISS, the Finnish Industrial Symbiosis system, this study investigates the dilemmas faced when organizing IS networks. It identifies openness and value demonstration dilemmas, which hinder intermediary-firm relations. It also identifies collaborative intermediation processes among intermediaries in seeking to uncover value, ensuring community embedding of new networks and selective integration of intermediation activities. These processes can help overcome the intermediation dilemmas. The results on the collaborative intermediation and its development over time contribute to research on facilitated IS and on intermediaries in sustainability transitions. For policy-makers, the study pinpoints the need for collaborative intermediation where both national and regional intermediaries are involved to ensure both economies of scale and flexibility.

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1. Introduction

Circular economy has emerged as an important vision, including a range of strategies to tackle sustainability challenges (Blomsma and Brennan, 2017). It has gained popularity in the business and policy arenas supported by organizations such as the Ellen MacArthur Foundation (Bocken et al., 2017), and also attracted a rapidly expanding body of research (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Murray et al., 2017). However, the transition to the circular economy requires vast changes in production and consumption patterns. This requires new types of technologies, products and business models and wider societal changes, and, if not 'designed' appropriately, the circular economy can lead to negative rebound effects and greater levels of material consumption (Zink and Geyer, 2017).

Industrial symbiosis (IS) is a key paradigm for achieving circular economy among industrial firms (Baldassarre et al., 2019), where co-located firms can create new value from former waste materials and resources (Chertow, 2000). Industrial Symbiosis integrates

cleaner production into the 'interactions of companies in a specific region or park with its local and ultimate global ecosystem', 'with the goal of matching industrial inputs/outputs to the real limits of Earth's carrying capacity' (Lowe and Evans, 1995, p. 47–48). It has been implemented as a viable business model innovation in existing firms, seeking to build new business opportunities, while resolving environmental challenges associated with their operations (Short et al., 2014).

However, achieving new IS projects often requires outside facilitation for several reasons (Paquin and Howard-Grenville, 2012). Firstly, information on waste and byproduct materials is not always readily available due to lack of trust or strategic interest, especially in regards to cross-industrial resources synergies (Zaoual and Lecocq, 2018). Secondly, the quality and quantity of waste and byproduct materials is dependent on main products, it may be difficult to optimize for customers (Bansal and McKnight, 2009). Thirdly, technological and regulatory barriers may prevent new symbiosis opportunities (Salmi et al., 2012). Various facilitated IS initiatives have sprung up around the world, and many have also caught the attention of researchers, such as the National Industrial Symbiosis Programme (NISP) in the UK, studied by Paquin and Howard-Grenville (2012).

* Corresponding author.

E-mail address: samuli.patala@aalto.fi (S. Patala).

Facilitated IS requires the effort of intermediaries that can perform various functions to accelerate new innovations for material reuse (Kanda et al., 2018). While intermediaries have recently caught the interest of scholars interested in sustainability transitions (Kivimaa et al., 2019), they have received less attention in the field of IS. This study explores a key challenge that intermediaries face in the facilitation of IS: how to provide value-adding intermediation over the long term to keep different partners committed to a network, and how they may overcome this challenge. It investigates activities of various intermediaries when they facilitate an IS network. The aim is to identify the challenges and hindrances in the intermediation process and the methods through which intermediaries can overcome these. The key research questions are: What kind of challenges hinder the development and facilitation of IS, and how do intermediaries overcome these challenges? How can collaborative intermediation processes contribute to IS development?

An in-depth case study of the largest facilitated IS network in Finland, called Finnish Industrial Symbiosis system, FISS was conducted. The network involves coordination between various types of intermediaries at both the national and local levels, making it especially suitable for studying collaborative activities between different types of intermediaries and firms within a facilitated IS network. The study will illuminate key dilemmas that hinder the relations between intermediaries and firms, as well types of collaborative activities that encourage the network's ongoing action. By identifying these counteracting forces, this work seeks to contribute to both the understanding of intermediaries in sustainability transitions as well as the work on facilitated IS.

2. Literature review

The literature review focuses on former studies of facilitated IS, followed by the role of intermediaries in sustainability transitions more broadly. It ends with the research gap, focused on understanding the dilemmas faced by intermediaries when organizing IS.

2.1. Facilitating industrial symbiosis

IS falls under the field of Industrial Ecology and studies material flows in industrial systems in order to advance change from a linear to a circular economy (Chertow, 2000). IS can be defined as “engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products” (Chertow, 2000, p. 331). While initial studies on IS focused on waste and byproduct synergies, later studies have broadened this to encompass other ways to use resources more efficiently, including for example the sharing of infrastructure and equipment (Lombardi and Laybourn, 2012). Yet later studies also focused on the business and strategic aspects of IS (e.g., Short et al., 2014, who explored IS as a business model).

The emergence and management of IS have been important areas of inquiry for IS researchers. Many early studies focused on the comparison between two archetypical models: self-organizing and centrally planned symbiosis (see e.g., Baas, 2011; Desrochers, 2004; Gibbs and Deutz, 2005). While successful examples of both extremes exist, more recent studies have acknowledged that many IS networks benefit from some degree of purposeful facilitation during their development (Boons et al., 2016), and even initially self-organized systems have often benefited from institutionalizing the IS actions (Chertow and Ehrenfeld, 2012). Facilitation can have various outcomes, depending for example on the IS network structure and the stage of development during which facilitation happens (Boons et al., 2016).

Various important intermediary actions in facilitated IS have

been identified. IS intermediaries play for example a key role in creating trust between previously unknown actors (Hewes and Lyons, 2008), and help build new network ties by brokering (Doménech and Davies, 2011). Intermediaries are important for institutionalizing IS through collective norms and governance mechanisms (Chertow and Ehrenfeld, 2012) and for raising awareness (Zaoual and Lecocq, 2018), which helps reduce mental distance between actors (Ashton and Bain, 2012). Organizations engaging in IS facilitation typically include government agencies or governmentally-owned organizations (Costa and Ferrão, 2010; Zaoual and Lecocq, 2018), but can also include various associations, NGOs, and private businesses (Walls and Paquin, 2015).

Although the promise of Industrial Symbiosis is considerable, active facilitation is still necessary to accelerate the sustainability transition (European Commission, 2015). For instance, the famous Kalundborg IS network developed over several decades (<http://www.symbiosis.dk/en/>), that is, not rapid enough, considering the urgency of many sustainability challenges (Martin, 2019). The wider CE literature has also acknowledged that public agencies' role has been found to be crucial for overcoming barriers to CE, for example in creating supporting infrastructures and promoting awareness (de Jesus and Mendonça, 2018). Despite the recognition of diverse intermediary roles, the literature on the challenges associated with intermediation activities is scarce. Hence, this study focuses on the challenges encountered by intermediaries in IS, and ways in which intermediaries can help overcome these.

2.2. Intermediaries in sustainability transitions

Intermediaries have recently gained wide attention in sustainability transition studies (Kivimaa et al., 2019). They can perform different functions and their roles have for long been studied in other contexts, including, e.g., distribution channels (Gadde, 2014) and international operations (Ahn et al., 2011). Innovation scholars have emphasized the role of intermediaries in the development and commercialization of new innovations (e.g. Howells, 2006). Intermediaries can, for example, broker new relations between suppliers and users of technologies, process information for new technologies and facilitate technological development (Howells, 2006), and they are often involved in various stages of the innovation process (Stewart and Hyysalo, 2008).

Three different roles of innovation intermediaries have been distinguished: facilitating (i.e., providing opportunities and space for other people to act); configuring (i.e., adjusting the material and symbolic form of technology), and brokering (i.e., establishing, nurturing, adjusting and altering of connections between different actors) (Stewart and Hyysalo, 2008). Kanda et al. (2018) identified several roles of intermediaries in supporting eco-innovation in particular, including, among others, forecasting and road mapping; fostering networking and partnerships; prototyping and piloting; technical consulting; and branding and legitimation. While these examples show the wide spectrum of potential intermediary activities, they focus on the positive potential of intermediaries. Less attention has been directed on the challenges that intermediaries face in their operations. To address this, investigations on ‘what’ intermediaries are doing, but also on context-specific studies revealing ‘how’ intermediaries operate (Hakkarainen and Hyysalo, 2016; Kanda et al., 2018).

Recent studies have paid attention to intermediation at multiple levels and by various intermediaries. Kanda et al. (2018) analyze eco-innovations and intermediaries as agents for accelerating sustainability transitions. Their cross-level study suggests for policy makers a complementary use of different types of intermediaries to support eco-innovation. Governmental intermediaries are especially important in transitions to more sustainable practices

(Kivimaa, 2014). In addition, some non-governmental organizations, referred to as 'modern environmental networkers' by Ritvala and Salmi (2010, 2011), have mobilized issue networks to solve environmental problems. Gliedt et al. (2018) analyze how sustainability-oriented innovation intermediaries link local, state and business actions, and show that this helps to scale-up and influence green economic development in a politically feasible manner, in particular when institutional uncertainty and instability prevail. These studies point to the need to understand operations of a network of intermediaries at different levels, and their collaborative efforts, as a factor for sustainability transition.

Intermediations are often seen as a temporary strategy; Ellis (2005) suggests that when an intermediary successfully increases the understandings and involvement between two parties, its services may become redundant, leading to a "trader's dilemma" phenomenon. Then again, the study of supply chains by Vedel and Ellegaard (2013) challenges this view and describes the (sourcing) intermediary as a persistent value-creating actor in the chain. Indeed, recent studies have focused on temporal dimension and survival of innovation intermediaries, that is, on their longevity, to understand sustainability oriented transformations (Kant and Kanda, 2019).

2.3. Research gap: intermediation dilemmas in industrial symbiosis

Several studies have attempted to link the concepts of sustainability transitions and IS. For instance Adamides and Mouzakitis (2009) and Susur et al. (2019) have utilized the socio-technical transitions –framework and analyzed IS networks as strategic niches that can catalyze sustainable innovations on the broader level. However, while several studies have analyzed transition intermediaries in a sustainability-related context (Gliedt et al., 2018; Kant and Kanda, 2019), an understanding of how they can promote IS networks in particular is lacking. Brokering has traditionally been important in IS intermediation, as firms with residual resources and firms with resource needs need to be matched, as found in the study of NISP UK by Paquin and Howard-Grenville (2012). IS intermediaries also need to interact with a complex network of participants from different sectors, which makes value creation through intermediation challenging, as it requires diverse technical and social skills. Hence, challenges such as the trader's dilemma (where the intermediary becomes bypassed) are likely to appear. It is therefore crucial to investigate IS intermediation over time, and what kind of challenges emerge in the intermediation processes. To better understand intermediaries' survival, it is important to understand the dilemmas they may encounter in their operations.

Secondly, while various intermediary roles have been identified in the literature (Kivimaa et al., 2019), less attention has been paid to the heterogeneity of organizations performing the intermediation. Previous studies have often treated IS facilitators as relatively homogenous types of actors performing similar functions, one example being public-sector brokering organizations (Zaoual and Lecocq, 2018). However, various types of intermediaries may form separate networks of relations among each other, and uncovering these is important for understanding of intermediation dilemmas.

This study delves into the dilemmas encountered by intermediaries and investigates how their collaborative actions can help in overcoming those dilemmas. It addresses current gaps in the literature by an empirical study in this specific context. The investigation concerns an Industrial Symbiosis network and its organizing over some time: during its inception and first years of operations. The case involves different types of intermediaries, operating at different scales from local to national.

3. Method

An in-depth case study was used as the primary research method for the empirical study. Case studies are especially useful for generating new theory about a phenomenon that is relatively unknown (Eisenhardt, 1989). They have been recommended as a key method to study business networks, as they allow for a multi-perspective contextual understanding and capture the inherent complexity and dynamism of networks (Halinen and Törnroos, 2005). For a single case study, exemplary cases with unusually revelatory power and good access are generally preferred (Yin, 2013).

Here, a single case study of a facilitated IS network was conducted. The network consists of a nationally coordinated program for promoting IS as well as regional networks for facilitating resource exchanges between firms. Thus, embedded within the single macro-level case, there were multiple sub-networks with related intermediaries. This analysis of multiple organizations involved in same types of activities, but in different localities, gave a rich basis for understanding intermediation practices. The units of analysis were the interactions within network-level relations (Provan et al., 2007) of the intermediaries.

To ensure deep understanding of the case, both informant and data triangulation were used. Multiple perspectives were reached by analyzing various types of network actors including intermediaries (e.g. local authorities, public sector organizations, consultancies and research organizations) and the participating industrial firms. Multiple informants were interviewed in those organizations where several individuals had been substantially involved in the network, while in some organizations only a single individual was involved, and consequently, interviewed (see appendix for the core interview themes). In addition to interviews, data was gathered through observations of key events in the network and using archival data. Data gathering in two main phases (2014 and 2016) enabled identification of development aspects within the networks.

3.1. Case description

The case study was conducted in Finland, where activities associated with IS have a long history, as firms from resource-intensive industries have reused byproducts and waste materials from their processes (Levänen, 2015). These activities have typically taken place inside the firm. One example is the forest industry, where black liquor is a byproduct of pulp production and is commonly used to produce energy.

In 2013, an official national network (Finnish Industrial Symbiosis system, FISS) was created to promote IS especially with an inter-organizational perspective. The program was modeled after the NISP in the UK. At the national level, the coordinators of the network promote IS by spreading awareness and organizing resource workshops. The program also operates on the regional level, where currently 14 of the 19 administrative regions in Finland have a designated coordinating organization to promote IS in its region. As of 2019, 623 firms with 4734 resources have been involved in the network's activities. A core activity in the network are 'resource workshops', where diverse firms in a region are brought together in a collaborative workshop. The firms list their excess resources as well as their resource needs, in order to find resource synergies with other firms. These resource flows are then presented in a national database in order to further facilitate resource exchanges. The program also promotes implementation of IS by helping the firms to find technical expertise, legal advice and funding.

In addition to the IS networks coordinated by the FISS, many IS

initiatives in Finland have started through self-organized network activities, a pattern found by Boons et al. (2016) as well. These networks also catalyzed the FISS network during its inception by providing initial case examples and sharing best practices. These IS networks, while more emergent in nature, had typically also institutionalized IS facilitation in some form. They typically had either a local economic coordinating organization or a private firm in charge of promoting further IS projects. Fig. 1 illustrates the structure of the FISS network.

3.2. Data collection

The objective of the study was to explore the challenges in intermediary activities in facilitating the IS network, and thus it sought for an in-depth understanding of the different interactions present in the network. The main units of analysis included two types of interactions within the multi-tiered network: intermediary-firm and intermediary-intermediary interactions. Data was gathered from various organizations acting as either intermediaries or IS participants in the network. Intermediaries were specified as organizations engaged in the promotion of IS without being direct participants (i.e. exchanging materials) themselves. Table 1 summarizes the data.

Data was collected through semi-structured interviews and observations in two phases. The first phase was conducted in Spring 2014, during the initiation phase of the launched national network. At this time, the activities within the network were being tested and refined. The second phase of data collection took place in Autumn 2016, to explore how the network had developed and to gain insights from new actors, who had joined the network since its initiation. The data thus captured the development of the network's interactions over a two-year period.

Data collection covered a diverse set of organizations that had participated in the network's activities. The network consisted of various organizations (intermediaries, participant firms and expert partners) acting on the national and/or regional levels. Interviewees included both intermediaries ($N = 10$) as well as participating IS firms ($N = 7$). In both phases, the data collection started by contacting the key coordinating organization of the network. Other suitable organizations were then contacted through the contacts and information provided by the network coordinator. The central coordinator was interviewed in both phases, but the other interviewees during the second phase were new intermediaries and firms that had joined the network. The primary rationale for choosing the informants from the organizations was their high degree of involvement in the network. Typically, each organization had one designated individual for the network's activities. The informants included mostly managers and experts. The interviews focused on the following issues: the organization's motives and key activities related to IS; the relations and

interactions with other network participants (firms/intermediaries), organization and coordination of network's activities, as well as the barriers and success factors related to the activities.

The interview data was triangulated through observations as well as secondary data. The observations focused on the network's key activities: two seminars, two site visits (one together with an intermediary) and one resource workshop. The archival data included the network's webpages, presentations, technical documents and research reports.

3.3. Data analysis

The data was analyzed through an inductive and interpretative method (Gioia et al., 2013). This qualitative data analysis method is based on a three-stage coding process, where descriptive first-order codes are abstracted and grouped into second-order codes, which in turn are linked to aggregate concepts that relate to major parts of the studied phenomenon (Gioia et al., 2013). The process involved developing first-order codes using the informants' concepts followed by aggregating these under second-order theoretical concepts. During the analysis process, the challenges identified were specified as *dilemmas* and the solutions to these challenges as *collaborative processes*. For instance, descriptions related to the challenges of information sharing, the underlying challenge related to openness (confidentiality), and the resultant need to retain semi-open access to information emerged as linked first-order codes; and these led to the abstracted concept of openness dilemma. This code, along with the value creation dilemma, formed the aggregate concept of intermediation dilemmas. The study found that the intermediation dilemmas emerged in the intermediary-firm relations, while the collaborative intermediary-intermediary relations could alleviate the dilemmas. Table 2 illustrates the process for generating theoretical categories.

4. Findings

This section discusses the findings of the qualitative analysis. First, it describes the organization of the network as a background for how the dilemmas emerged. Then, it focuses on the dilemmas associated with intermediating IS, and finally, elaborates the collaborative intermediation processes, which emerged as solutions to alleviate the dilemmas.

4.1. Organization of the network

Diverse types of organizations from multiple levels (national and regional) were involved in the IS intermediation processes. The key intermediary across the whole network was Motiva, a governmentally owned company providing expert services to firms

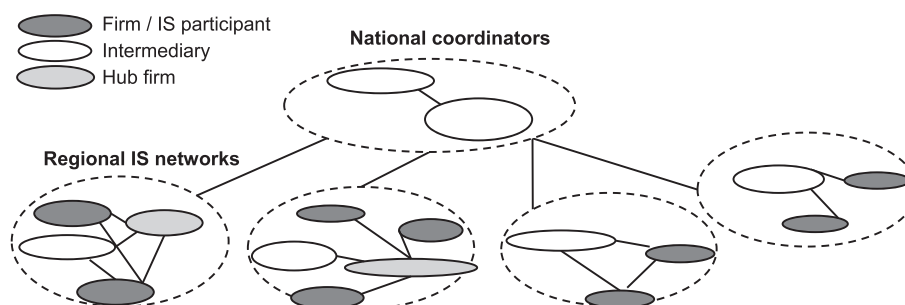


Fig. 1. Structure of the FISS-network (partial network model for illustrative purposes).

Table 1
Data collection summary. Note. Brackets[] list the number of interviewees per organization.

Interviews	Observations	Secondary data
1st round (2014) Organizations interviewed [number of interviewees]: Six intermediaries: energy and material efficiency service provider[3], innovation fund[2], two regional development organizations [1 each], environmental consultant [1], university [1], technical research centre [1] Five participant firms: Metals recovery [1], food waste reprocessing solutions [1], waste management services [1], biofuel production [1], waste management technology [1] Total: 11 organizations and 15 interviewees (150 pages of single-spaced transcriptions)	2 seminars (12 h, 15 pages of field notes) 1 IS site visit (4 h)	Archival documents: Eco-industrial park reports (N = 3) FISS industrial symbiosis case studies (N = 20)
2nd round (2016) Organizations interviewed [number of interviewees]: Five intermediaries: energy and material efficiency service provider [1], four regional development organizations [1 each] Two firms: Food waste reprocessing [1], granite production [1] Total: 7 organizations and 7 interviewees (55 pages of single-spaced transcriptions)	1 resource workshop (3 h, 5 pages of field notes) 1 site visit with an intermediary (6 h, 5 pages of field notes)	Archival websites: FISS website Coordinator webpages (N = 7)

Table 2
Coding structure.

Aggregate concepts	Second order codes (explanation)	First order codes
Collaborative intermediation processes	Intermediation dilemmas	
	Openness dilemma (Tension between open and closed access to resource information)	<ul style="list-style-type: none"> • Open information sharing as a principle • Confidentiality issues in information sharing • Semi-open access to information system as a solution
	Value demonstration dilemma (Tension between broad brokering vs. providing more specialized services)	<ul style="list-style-type: none"> • Losing access to firms after initial brokering • The value of the network's activities to the firms • Service provision vs. broader collective action
	Uncovering value (Encouraging simultaneous creation of economic and environmental value)	<ul style="list-style-type: none"> • Finding systemic interconnections through multi-disciplinary learning • Building an expert network • Finding ways to valorize environmental benefits
	Community embedding (Shift towards collective action thinking among co-located firms)	<ul style="list-style-type: none"> • Community development • Utilizing informal networks • Leveraging local champions • Sharing assets
	Selective integration (Selective homogenization of certain intermediation practices, while maintaining diversity in some areas)	<ul style="list-style-type: none"> • Standardizing best practices • Maintaining local flexibility and distinctiveness • Inter-regional competition as a risk

for improving resource and energy efficiency. In the beginning, a governmentally owned innovation foundation, Sitra, was also involved. As the network developed, Motiva assumed sole responsibility for coordination on the national level. After the start-up phase, it set up regional coordination, with designated intermediaries, which included regional development organizations, universities and research centers, as well as a sustainability consultant firm. IS participants were firms from various industries, which typically, had waste material or byproducts that were left unused, taken to landfill or used in low-value exchanges. Their business interest in IS was therefore to avoid waste management costs or to find higher-value opportunities for recycled material. Other firms were looking for new suppliers of materials for their own processes.

A key activity of the intermediaries was to raise awareness on IS, through e.g. seminars. Secondly, the intermediaries facilitate connections between firms. A key method for this were resource workshops, where firms co-located in a specific region listed their excess resources as well as resource needs. More focused workshops were organized around specific materials and for selected participants to increase potential for finding resource synergies. The regional intermediaries also utilized informal networking events for building trust among participants. Thirdly, the intermediaries facilitated open sharing of information in the network. For instance, the intermediaries gathered knowledge of best practices for IS on a national scale, as well as maintained a database of resources available for IS. While many connections

were established in the workshops, the resource database allowed the intermediaries to find potential synergies beyond their scope and even on cross-regional scale. In addition, the intermediaries also developed a map of IS sites in Finland, which was posted on the program's official webpage and thus made available to the public. Lastly, the national coordinators also developed and maintained a network of experts, who could be called upon for providing technical knowledge for specific IS projects.

4.2. Dilemmas in the network development

The analysis of the actions of the intermediaries and the responses of the involved firms identified two major issues that hindered the networks' potential to grow and achieve its targets. These are labeled here as *dilemmas*.

4.2.1. Openness dilemma

The first observed dilemma, referred as the 'openness dilemma', relates to the sharing of information in the network. The network's actions are dependent on open sharing of resource data from participating firms, but simultaneously, this may become a confidentiality issue for the firms. Freely available information on resource data may give away competitive information. The network development, however, required that firms were willing to share information in the resource workshops. Identifying resource synergies required firms to share detailed data on the type, quality and quantity of resources that they had available. Some firms were

hesitant to share the information completely due to confidentiality reasons:

"Although we are progressing towards more open use of data, some of the workshop participants are still skeptical about sharing all of their resource data. They wish to know who will use the information and how." (Senior expert, national development organization)

The intermediaries addressed this by making the information only partly open. In essence, the resource database was only accessible to the intermediaries themselves. They were in charge of inputting resource data into the system from the companies, as well as identifying potential opportunities through the system.

4.2.2. Value demonstration dilemma

The second key challenge in the network's functioning related to the value of the network's activities to the firms. This is referred here as the 'value demonstration dilemma'. Firms receive potentially valuable support from the intermediaries, which can result in IS relations with economic and environmental benefits. However, after receiving information from the network and finding a potential partner for IS, firms can continue the development of the symbiosis project by themselves. Indeed, the intermediaries mentioned that they had only limited information about which symbiosis projects proceed beyond the initial recognition of the opportunity without the intermediary:

"Often, the firms will continue the development of the IS project independent from the intermediary." (Senior expert, national development organization)

This created a problem for the intermediaries, who had to demonstrate successful outcomes of the network in order to secure further public sector funding for the network. This was usually achieved with projects where the symbiosis was relatively straightforward to implement without the need of additional technologies. However, in many cases, the exchanges were more complex and required some kind of additional resources in order to be implemented. For instance, technological expertise or new investments into equipment to reprocess the waste were needed, or the firms were hesitant to proceed without public funding or support for the required investments. This dilemma could potentially be addressed by offering higher value, more focused services to the firms. However, the intermediaries often did not have enough resources for this, and they felt it would detract from the broader reach of the network's activities. In essence, the intermediaries did not want to become a dedicated service organization, but rather maintain collective functioning of the network.

The openness dilemma and value dilemma are interrelated. If firms do not see value in participating in the network, they are hesitant to share information. Similarly, if firms are hesitant to provide information for confidentiality reasons, it hinders the intermediaries to develop the network and provide value for firms. The dilemmas thus potentially lead to a vicious cycle, which hinders growth of the network.

4.3. Collaborative intermediation processes

In addition to the two hindering dilemmas, three specific collaborative intermediation processes were identified. Through these the intermediaries could alleviate the aforementioned dilemmas and this contributed to the IS development. These are described below.

4.3.1. Uncovering value

Firstly, one key process related to uncovering latent value potential through the network's activities. Several respondents noted that the program had been successful in changing some firms' perceptions to view waste as a potential input to other industrial firms.

"It's important to change the way waste is viewed. It shouldn't be just about finding the cheapest way to get rid of waste but really thinking about what's in it. What is waste for others, is resources for us. There should be more focus on seeing the potential and making something new, in some cases it can be even an exportable product." (Development manager, Biofuel producer)

Many firms saw themselves as forerunners in this regard. In many cases, the firms had a manager with a multifaceted industrial background or a team with diverse experience, which enabled them to recognize opportunities for IS. Firms active in IS also mentioned that it was vital to keep an open mindset towards new relationships. Many industrial firms typically collaborate with partner firms, but only in their supply chains. However, IS often requires collaborating with firms from other industries. Several respondents mentioned that this requires an openness towards new relations and willingness to collaborate with new partners, which not all firms had:

"Seeing the bigger picture is vital, understanding the other industrial who can use your materials ... and this can be difficult especially for SMEs focusing on their core business." (Expert, environmental consultant)

Collaboration between the intermediaries was vital for identifying new value potential. For instance, the intermediaries developed an expert network that could be utilized to develop potential resource synergies. These included e.g. technical experts who could provide consulting to realize resource synergies, regulatory experts who could help with permissions, and business development experts.

A business case was often mentioned as a critical factor for IS to happen, usually achieved by avoiding the costs of waste management (such as landfill taxes) or gaining extra revenue from selling the material. But the forerunner firms also had a high emphasis on environmental values, as enablers of IS:

"For more and more firms, the motive is also to increase their profile as an environmentally aware company." (Project Manager, Regional development organization)

Reusing wastes and byproducts allows firms to decrease environmental impacts associated with waste management, such as land use and hazardous emissions to ground and water. Decreased water use and carbon footprint were also mentioned as other benefits. For instance, one firm manufacturing granite products noted that the largest environmental impact from their operations was the stone scrap constituting about 80–85% of the total mined material. The scrap is stored in piles, which lead to landscape impacts. The firm was highly interested in an IS, which would allow them to decrease the amount of this scrap material. Many of the respondents mentioned that the concern for environment was part of their personal values. Especially for smaller firms with an environmentally aware founder or CEO, these values were usually also ingrained into the organization.

In addition, the firms' public image and green marketing activities also factored into the motivations to engage in IS. Firms with a

high need to express a sustainable image, e.g. consumer-facing firms, had a higher motivation to engage in IS for public image purposes. Potential for green marketing, for example, the ability to use certification and standards, also had an effect. For example, the end-of-waste criteria developed by the European Commission were mentioned as an emerging certification method, which would make it considerably easier to market products using recycled material.

4.3.2. Community embedding

Another process related to building local community relations, which enabled firms to develop a mindset for collective action in resource sharing. Such collective logic was also evident in social benefits as a motive for IS. These arguments usually concerned community values and benefits to the local economy. IS generally focuses on local collaborations and many firms preferred working together with local firms whenever possible, and they valued the benefits provided for the local industrial relations. Many informants also mentioned that IS could improve local employment and economy, as well as bring additional services to the region.

The intermediary collaboration for community embedding was evident through the relations between the national and local intermediaries. While the national intermediaries were often involved with setting up the resource workshops and maintaining the resource database (that is, brokering), they encouraged the local intermediaries to set up initiatives to foster deeper local collaboration beyond resource brokering. The local intermediaries in turn commonly relied on the help of champions, entrepreneurial individuals who could contribute to building local IS networks (Kokoulina et al., 2018). Champions, while often being participants in IS themselves, could also act as intermediaries to expand the reach of IS activities.

Infrastructure and facility sharing are typically seen as the second form of IS, in addition to resource links between firms (Chertow, 2000). Many respondents mentioned that while they had previously considered the value potential of wastes and byproducts, infrastructure sharing was a considerably less obvious activity for them. The sharing activities were focused commonly on industrial facilities and equipment, such as laboratory space, pilot/test equipment, etc. These facilities and equipment could be rented out to other firms in the area, improving their utilization rate and providing additional revenue to firms. The collective logic is potentially at odds with the conventional closed form of innovation. Outside partners are not always allowed to operate in a firm's premises or share infrastructure for the potential fear of losing intellectual property.

"There's a lot of unused facilities in this area which could be used to make new symbioses. And I don't mean only reusing byproducts but the kind of symbiosis where we can utilize the same laboratory space, same staff, same brains." (CEO, metals recovery firm)

4.3.3. Selective integration

A third set of coordinated processes among the intermediaries concerned the selective integration of intermediation activities. This served the purpose of taking advantage of economies of scale by homogenizing certain intermediation activities (e.g. information sharing), while retaining flexibility for local intermediaries to provide value creation that benefits from local distinctiveness.

Firstly, the intermediaries aimed to maintain and develop the nationwide database of resources (and resource needs) available for IS. The data collection practices were therefore homogenized so that each intermediary would use the same format for collecting information from the resource workshops. In addition, the

intermediaries jointly maintained other forms of information on a website, including a collection of case examples of best practices of IS. They also developed a map of known IS projects across Finland, which included both projects initiated through the intermediary activities as well as self-organized networks.

On the other hand, the governance structure of the system gave the intermediaries considerable flexibility in providing tailored value-adding intermediation activities. While the aforementioned activities related to information sharing and brokering were coordinated nationwide, many of the local intermediaries developed their own intermediation actions within their localities, often in the form of a separate project. These activities included for example material and energy audits, helping with obtaining ecolabels or standards, as well as regional planning activities at more specific eco-industrial parks.

I see it as really important that on the national level we have some degree of similarity and direction. But on the other hand, this local coordination has to also be involved, as some of the collaborations we have do are very locally situated (Project manager, University)

These localized practices helped the intermediaries leverage local distinction for IS. Many of the IS sites in the network had more specific industrial profiles (such as agriculture, bioenergy, or quarrying) with associated material streams. In some cases, this helped participants to develop a specific "identity" for IS in the region, which contributed to the community embedding activities. Yet, according to the national intermediaries, a potential downside of strong local distinctiveness is that local intermediaries start to compete rather than collaborate with each other for waste and byproduct streams.

The potential challenge of having too many different agencies and areas of governance is that they tend to start to compete with each other. Which can lead to sub optimization. (CEO, biofuel producer)

5. Discussion

Intermediation and intermediaries have been extensively studied in relation to sustainability transitions (Kivimaa et al., 2019), but so far little attention has been given on how various intermediaries can promote IS networks in particular. To address this gap, this study investigated the national IS network FISS in Finland, and its organizing during the first years of operations. Furthermore, the focus on collaborative actions of various intermediaries and intermediation targeted at different levels provided us new understanding of cross-level intermediation processes. This study has two main contributions. The first contribution relates to the identification of key dilemmas in IS intermediation and the collaborative actions that intermediaries took to overcome these. The second contribution relates to uncovering interactions among different intermediaries and developments over time. Fig. 2 illustrates these mechanisms in a framework, discussed in more detail next.

Two key dilemmas were observed from the study of IS network FISS: the openness and value demonstration dilemmas. The *openness dilemma* challenges intermediaries' brokering activities as they depend on firms being willing to reveal information on their resources to the larger IS network. Hence, social skills of the intermediary are essential as it may act as the trusted broker between companies of essential IS information. The *value demonstration dilemma* refers to the risk that firms disengage from the network after initial participation unless the intermediaries can sustain their

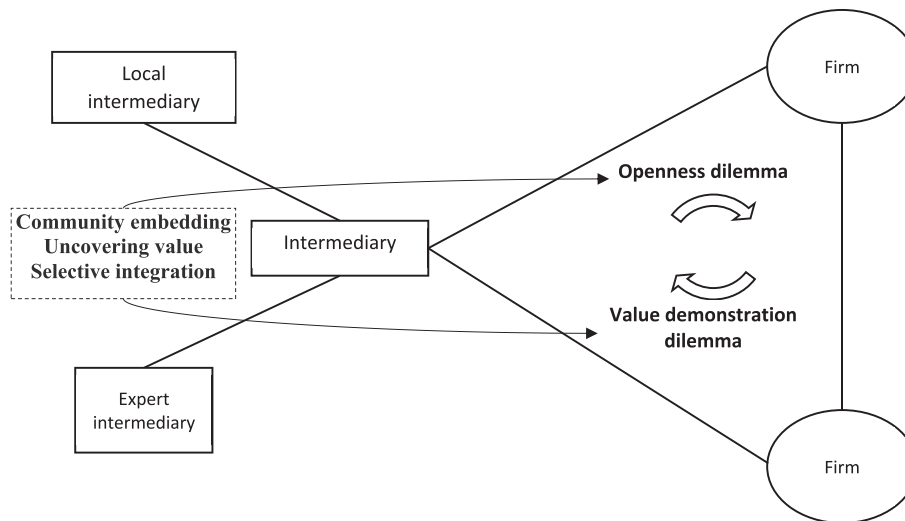


Fig. 2. Framework of intermediation dilemmas and collaborative intermediation processes. The lines represent interactions and arrows illustrate mechanisms. The rectangles represent intermediaries.

value-creating activities. While individual firms have turned IS into a source of competitive advantage (e.g. Short et al., 2014), it appears that intermediaries have an important role in highlighting the combined business and environmental opportunities of IS. Together, these dilemmas can lead to a vicious cycle for IS, as intermediaries depend on information to provide more value, and require proof of value creation to gain additional funding to sustain their activities.

Furthermore, the study showed how the coordinated actions of an intermediary network help overcome these dilemmas. Firstly, the intermediaries were able to leverage inter-disciplinary knowledge networks to better identify value creation possibilities of IS, which could alleviate the value creation dilemma. Secondly, the intermediary network relied on the local knowledge and relations in order to promote the community embeddedness of IS within specific regions, promoting engagement through norms and informal relations. This could alleviate both the value creation dilemma by identifying new ways for actors to benefit from their local networks, while building trust which is an important antecedent for openness (Walls and Paquin, 2015). Thirdly, the intermediary network utilized selective integration of activities, where certain processes such as information sharing were standardized, but flexibility and emergent action were retained for additional tailored intermediation activities. This process, in turn, required a balancing act. While high integration could facilitate openness due to having a larger pool of valuable data available, more tailored activities could provide higher value to specific participants. These coordinated activities and collaboration help to understand how intermediaries may sustain their actions in the face of challenges that threaten their survival. Many studies have highlighted the importance of intermediaries in catalyzing sustainability transitions (Kivimaa et al., 2019). However, intermediaries - who typically receive public sector funding to facilitate industrial activities - often have to cope with the operational logics of both the public and private sector, making their ongoing survival challenging (Jay, 2013).

This study's findings help understand how interactions of different intermediaries may unfold as development patterns of IS. Specifically, the intermediary interactions in FISS highlight a particular development path of facilitated IS. First, an initial intermediary adopts the concept from existing examples (NISP in this case) and engages in pilot facilitation and dissemination. In order to

overcome the intermediation dilemmas that emerge, this is followed by brokerage and collective learning models in local contexts as other intermediaries engage with the aim to develop local IS networks. These local networks in many cases also build on existing relations (i.e. self-organized networks). As the field of IS matures globally, and best practices are disseminated across countries, it is suggested that this development path can be a typical way how multi-tiered, national programs for promoting IS develop.

To conclude, the present study adds further support to past studies of facilitated IS, which suggest that intermediaries need to proceed gradually towards higher value exchanges as the network develops (Paquin and Howard-Grenville, 2012). Opportunities for simple brokering activities (which are temporary by nature) and low-hanging fruits are exhausted as the network develops. The longevity of intermediation activities thus depends on the ability to catalyze higher-order processes for collective learning.

5.1. Theoretical implications and future research directions

The findings have important implications for the research on transition intermediaries as well as facilitated industrial symbiosis. Industrial Symbiosis is one of the core practices of the wider circular economy (Ghisellini et al., 2016), with its focus on forming closed-loop resource links between and inside firms (Mulrow et al., 2017). Intermediation has been recognized to be a key process to overcome barriers and accelerate the development of IS networks (Zaoual and Lecocq, 2018).

The first theoretical contribution is to the study of intermediaries in sustainability transitions. Many existing studies have identified a multitude of roles for intermediaries and the processes and activities associated with those roles (Hakkarainen and Hyysalo, 2016; Kanda et al., 2018). However, this research has had a largely static view of intermediaries that does not consider their temporal development or the potential challenges related to intermediation. Only recently have scholars paid attention to how intermediaries sustain their activities over the long term, and a recent study by Kant and Kanda (2019) identified how the characteristics of an intermediary affect its survival over time. The present study contributes to this stream of research by shedding light on two intermediation dilemmas. These form a key barrier to intermediaries' ongoing activities and their relations with IS participants. Moreover, the study looked beyond intermediaries'

internal characteristics affecting their survival, and identified collaborative processes among different intermediaries as a key remedy to the dilemmas.

By providing insights through studying the FISS network and the involved intermediaries, this research aims to inspire further work on the dynamics of facilitated IS and intermediaries' role in it. In particular, comparative case studies of facilitated IS programs could expand these findings. Such studies would help understand the effect of contextual conditions (e.g. type of economy, regulatory environment, cultural norms) on intermediation. It can also help understand the role of facilitation and intermediaries in IS programs where the degree of government planning is high. As various national level IS programs mature, there is considerable potential for conducting such studies across borders. Despite the identified challenges, the present study demonstrated the important role of active intermediation for promoting IS, beyond self-organized IS. The findings may also have implications for other CE models beyond IS, as demonstrating economic value has been identified to be a critical part of realizing CE projects (Ngan et al., 2019), especially for SMEs (Paletta et al., 2019).

The second theoretical contribution concerns facilitated IS where interactions of an intermediary network in the facilitation process were elaborated. Past studies have identified roles of intermediaries in IS (Zaoual and Lecocq, 2018), but have paid less attention on the interactions among different intermediaries or the longevity of intermediary activities. Recent studies on the development of IS have highlighted multiple dynamics where intermediaries can play a role (Boons et al., 2016). The process outlined here takes the understanding of these dynamics further by elaborating how the individual dynamics can become patterned during longer-term development processes, as well how the dynamics can intersect between different levels of analysis (national and local).

5.2. Implications for practitioners

This research has several implications for practice and policy-making in IS.

Firstly, the study highlights the importance for intermediaries to establish and cultivate relationships not only with potential target firms for IS, but also other complementary intermediaries. This is a shift in perspective as an intermediaries' primary relations are usually considered to be its clients. Intermediaries may even be tempted to compete with each other for clients and resources, but this study found that collaborative intermediation can help overcome some of the fundamental challenges of intermediation, such as the value demonstration dilemma and openness dilemma, by identifying more value potential through a network—approach and helping generate trust by community embedding. In a similar vein as a firm's value creation network is considered a crucial part of its business model (Bocken et al., 2017), this study suggests that it is important for intermediaries to also consider their own intermediary network for value creation.

Second, for IS facilitation programs designed to involve collaborative intermediation from the start, the study recommends to choose the right type of actors to act as intermediaries. It identified community embedding to be a key collaborative process for overcoming the dilemmas, and it is important that the involved local intermediaries are able to develop this. In short, local intermediaries need relational capacity (Boons and Spekink, 2012) for their intermediation. Thus, existing local economic development agencies and hub firms have important advantages as intermediaries compared to external or new intermediation entities. Reflecting on the identified development path, this study concludes that while it is important for governments to initiate

intermediation programs, it is equally important to provide support in the critical phase where intermediation moves beyond initial brokering and identifying low-hanging fruits to deeper, locally-embedded value creation activities.

Thirdly, the identified selective integration processes show the need to maintain a degree of flexibility in facilitation programs. Some intermediation mechanisms, such as information sharing, clearly benefit from standardized practices, which allow information to be aggregated to resource databases. However, many value-creating network activities may be uncovered through localized IS knowledge and relations. It is therefore important for local intermediaries to be able to customize and tailor their activities in their respective local networks (Mignon and Kanda, 2018).

6. Conclusions

Industrial Symbiosis is one of the key pillars of circular economy, and active facilitation is often needed to accelerate its emergence and development. This study focused on intermediation in facilitated IS, by uncovering intermediation dilemmas and the collaborative intermediation processes, which help overcome the dilemmas. Understanding these dilemmas is important for intermediation in IS as well as for intermediation in sustainability transitions in general. Past research has shown that intermediaries are vital for accelerating sustainability transitions, and often governmental support for such activities is justified. However, as the FISS case showed, governmental backed initiatives are still accountable to demonstrate the impacts of their activities. Understanding the dilemmas faced by intermediaries is critical for policymakers to make better-informed decisions on intermediation programs. For instance, a seemingly ineffective intermediation initiative may require additional supportive functions from other types of intermediaries to create impact. Moreover, since joint value creation and openness are key parts of any collaboration, these findings are expected to be generalizable beyond IS.

Many studies have shown that intermediation is crucial for accelerating development towards industrial symbiosis, and more widely, circular economy. It is thus important to understand how intermediaries can maintain their value-creating services over time. This study has shed light on this topic through the intermediation dilemmas and collaborative processes, which can emerge in facilitated industrial symbiosis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRedit authorship contribution statement

Samuli Patala: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Asta Salmi:** Conceptualization, Writing - original draft, Writing - review & editing. **Nancy Bocken:** Conceptualization, Writing - original draft, Writing - review & editing.

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Appendix

Interview themes. Questions varied depending on the type of organization (intermediary or firm):

1. **Background-** Interviewee and organization background. Involvement in industrial symbiosis (IS)
2. **Drivers-** Motives for IS, history of the IS project, reception to facilitative actions (if intermediary)
3. **IS interactions and development processes-**actors involved, relations and interactions with other actors (firms/intermediaries), development process of an IS project, achieved results, challengers and enablers, role of social networks
4. **Facilitation structures:** facilitative mechanisms and activities, Responsibilities of coordinators, roles of different regional actors, needed infrastructure (e.g. IT systems), knowledge management in the network, funding, regulations

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