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Review

The Importance of Individual Actor Characteristics and Contextual Aspects for Promoting Industrial Symbiosis Networks

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Abstract: Factors that affect and influence industrial symbiosis (IS) collaborations have been researched extensively in the literature, where they are mostly reported at a network level or for IS in general, and lack the individual actor's perspective. This review article contributes to and expands knowledge of influencing factors and their effect on the individual actor. In a systematic review, guided by the PRISMA 2020 guidelines, this study reviews 53 scientific papers examining planned or existing IS networks. It examines literature from 1 January 2000 to 28 March 2022, and it identifies drivers, barriers, and enablers influencing actors to participate in IS. It explores whether and how the perception and impact of these factors differs depending on the characteristics of individual actors and their specific context. The main findings of this study reveal that an actor's specific characteristics and the network's context have a significant impact on decision making and how actors both perceive and are affected by factors influencing collaboration. Furthermore, an additional novel contribution to this field of research is that the study identifies three underlying and recurring considerations that actors appear to find critical, namely, perceived business opportunities/risks, regulatory and political setting, and potential inequalities in the network. The results show that an actor's take on these critical considerations determines whether the actor is willing to engage in IS.

Keywords: industrial symbiosis; urban symbiosis; drivers; barriers; enablers; literature review

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1. Introduction

Industrial symbiosis (IS) has gained increasing attention both in research and in the political arena as a successful means of moving towards a circular economy (CE). For instance, the European Commission has recognized IS as one important approach to close material loops and increase resource and energy efficiency [1]. In short, IS typically entails collaborations between different independent actors exchanging byproducts, e.g., excess heat or waste materials, to increase energy and resource efficiency. The purpose of symbiosis collaborations is to reduce the use of primary energy and virgin materials and thereby decrease adverse environmental impacts while typically saving costs [2]. In later years, the concept of IS collaborations was developed to include urban resource collaborations, sometimes referred to as industrial and urban symbiosis [3]. In the last decade, the definition of IS collaboration has been broadened even further, coming to include not only physical resource exchanges but also other types of sharing practices, such as the sharing of assets, logistics, knowledge, and information [4,5].

Recent research on IS highlights the competitive advantage that IS collaborations entail [6–8]. For example, Fraccascia et al. [6] investigate how and why firms can gain a competitive advantage by initiating IS collaborations. In addition, Razminiene et al. [8] contribute to the knowledge on the competitive advantage of IS when they investigate the relationship between cluster performance and shifting to a CE approach within the cluster. In this context, IS is considered a type of cluster collaboration. They find that there are potential cluster performance gains from adopting a CE approach. While this sounds promising, the potential of IS has been far from realized.

Factors that affect and influence the implementation of symbiosis collaborations have been researched extensively in recent years [3,9–12]. These influencing factors are commonly referred to as drivers, barriers, and enablers [10]. Drivers are elements that incentivize collaboration, e.g., economic, environmental, and social benefits. Barriers, on the other hand, work in the opposite direction and inhibit symbiosis initiatives. Finally, enablers are factors that can potentially enhance collaboration by removing barriers or creating drivers.

The literature suggests that drivers, barriers, and enablers for IS collaborations differ between different contextual settings. For instance, IS collaborations in an urban setting can experience different drivers or barriers from purely industrial collaborations [3]. Fraccascia et al. [10] review drivers, barriers, and enablers for energy-based symbioses and show that the influencing factors differ depending on whether the symbiosis is based on energy cascading, fuel replacement, or bioenergy production. Sectoral affiliation is another aspect that has been shown to have an impact on the perception of what inhibits or enables collaborations [11]. In summary, previous studies within the IS literature have found that the type of symbiosis network, sector affiliation, and urban (or geographical) context affect the drivers, barriers, and enablers of IS. However, most studies about IS use the network as the unit of analysis. In reality, however, a basic characteristic of symbiosis collaborations is that they consist of multiple independent, potentially heterogeneous actors that collaborate on non-utilized or leftover resources. It is very plausible that these actors experience different drivers of, barriers to, and enablers of IS collaboration. Research investigating IS from an individual actor's perspective will add knowledge to the field.

In this study, actors refer to public authorities, publicly owned companies, private companies, and different types of associations. An IS network can consist of a mix of all the above. Independent actors can be assumed to be inherently different and to have their own set of preferences that affect their strategies and the choices they make [13,14]. The reasons why individual actors within a symbiosis network decide to participate in a collaboration may differ depending on their own specific set of preferences and the context in which they operate.

Walls and Paquin [15] find that there is insufficient research at the individual actor level in IS. They specifically point to the lack of research on decisions by individual firms to participate in symbiosis collaboration. Studying the individual actor level may contribute important insights on the success of network implementation [15]. The knowledge gap on the individual actor level perspective identified above calls for a thorough review of the literature on drivers, barriers, and enablers, and how the literature addresses the individual actor's perspective. Consequently, the aim of this article is to contribute to and expand the understanding of the individual actor level perspective in IS collaboration. The objectives of this paper are (1) to identify factors, i.e., drivers, barriers, and enablers that influence decisions by actors to participate in symbiosis collaborations and (2) to explore, based on the current literature, whether and how the perception and impact of these factors differ depending on individual actor characteristics and specific contextual aspects.

Section 2 presents the methodology, describing both the literature selection process and the review process. Section 3 presents the main findings from the review process and an analysis, where the individual actor level perspective contributes an additional dimension to current knowledge on influencing factors. A concluding discussion is provided in Section 4, placing the results and analysis into a wider context. This section also suggests directions for future research.

2. Methodology—A Systematic Literature Review

Watson and Webster [16] argue that the main contributions of a literature review should be to provide a synthesis of current knowledge within one research field and to further develop the theoretical directions for the benefit of future research. A systematic literature review was conducted to fulfill the purpose of this paper, as defined in Section 1. The steps of the search and review procedures are explained in this chapter.

2.1. Literature Selection Process

The literature selection process for this paper was inspired by the updated PRISMA 2020 guidelines and is illustrated in Figure 1 [17]. The selected search strings for this study were "industrial symbiosis" OR "urban symbiosis" in combination with one of the following words "drivers", "incentives", "barriers", "obstacles", OR "enablers". The last search was conducted on 28 March 2022. The search strings are presented in full in Appendix A.

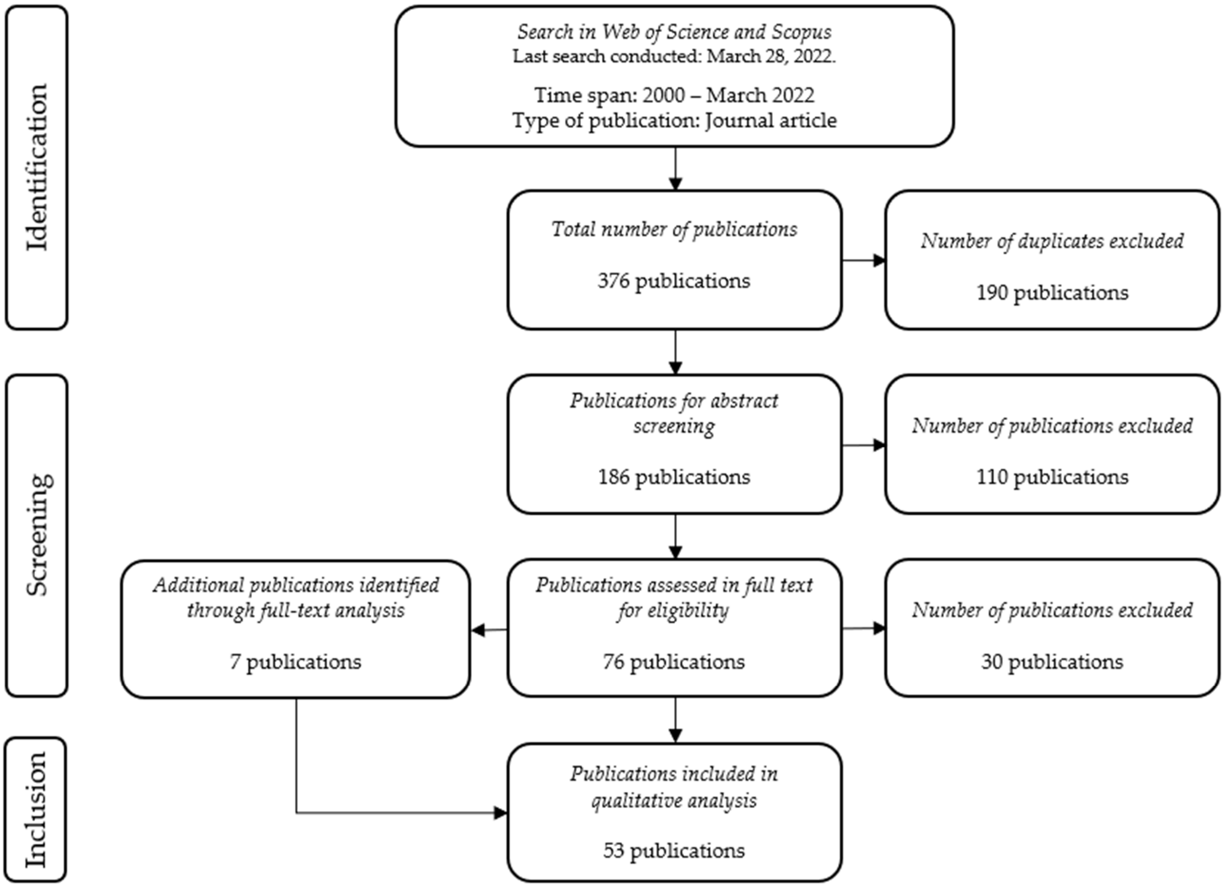

Figure 1. Flow chart of the literature selection process. This flow chart is inspired by the updated PRISMA 2020 guidelines [17].

The scope of the literature review was limited by a couple of constraints. The search was restricted to peer-reviewed research articles published between January 2000 and March 2022. The literature search was conducted in the databases Web of Science and Scopus, resulting in 376 publications. The results in Web of Science and Scopus overlapped to some extent and duplicates between the databases and search strings were excluded, rendering 186 publications for abstract review. To be included in the sample for full-text screening, the abstract was required to include either "industrial symbiosis" OR "urban symbiosis" in combination with at least one of the search words mentioned above. Publications not meeting these criteria were excluded from further analysis. The abstract review resulted in 76 publications eligible for full text assessment. The full text assessment focused on identifying the context in which the search words appear and whether the scope of the publication was relevant for the review. The relevance criterion was that one of the main contributions of the publication was to study influencing factors. As such, it needed not only to be mentioned as a sidenote, but also to be an essential part of the results and analysis. The full text assessment excluded another 24 publications, resulting in 46 publications for further analysis. While conducting the full text assessment, an additional 7 publications were identified as relevant for the review. Thus, 53 publications were included in the final sample for review and qualitative analysis. The literature selection process is illustrated in Figure 1.

2.2. Literature Review Process

A literature review matrix was created to systematically document the main contribution of each article and its relevance to this review. The final literature sample was coded and analyzed qualitatively using the QSR International software program Nvivo. The coding in Nvivo was conducted to organize different influencing factors into either drivers, barriers, or enablers. First, this article refers to drivers as elements that incentivize participation in symbiosis collaboration, e.g., economic, environmental, and social benefits. Drivers can also be factors that force (e.g., mandatory regulation) organizations to improve their environmental performance by increasing resource efficiency through symbiosis collaboration. Second, barriers refer to factors that are perceived as inhibiting the symbiosis initiatives. Third, enablers refer to factors that can potentially enhance collaboration by removing barriers or creating drivers.

In the coding process, each factor was assigned to a keyword or a key phrase. In Nvivo, these are called codes. Subsequently, the codes were categorized as either a driver, a barrier, or an enabler. When the same, or a similar, factor was mentioned several times in different articles, it was assigned to the existing code. This procedure rendered 436 codes in Nvivo, of which 215 were assigned to barriers, 114 to drivers, and 109 to enablers. The coding of drivers, barriers, and enablers from Nvivo was individually exported to Microsoft Excel for further processing. In Excel, the codes of influencing factors were analyzed one by one. By analyzing the influencing factors one by one, it was possible to identify iterations, similarities, and themes within the codes. This procedure made it possible to merge the codes into bundles in which all factors referred to similar or related topics. This procedure was iterated and resulted in the formation of six categories. To further analyze and make sense of the results, an additional level of sub-categories was created along with specific examples. To be able to systematically analyze whether and how the individual actor characteristics and contextual aspects were acknowledged in the literature, an additional set of codes was also created in Nvivo. Articles were coded separately and labelled accordingly where authors explicitly recognized a difference in how influencing factors were perceived or how they affected individual actors differently, depending on their specific characteristics and contextual aspects. The review and coding process is illustrated in Figure 2 below.

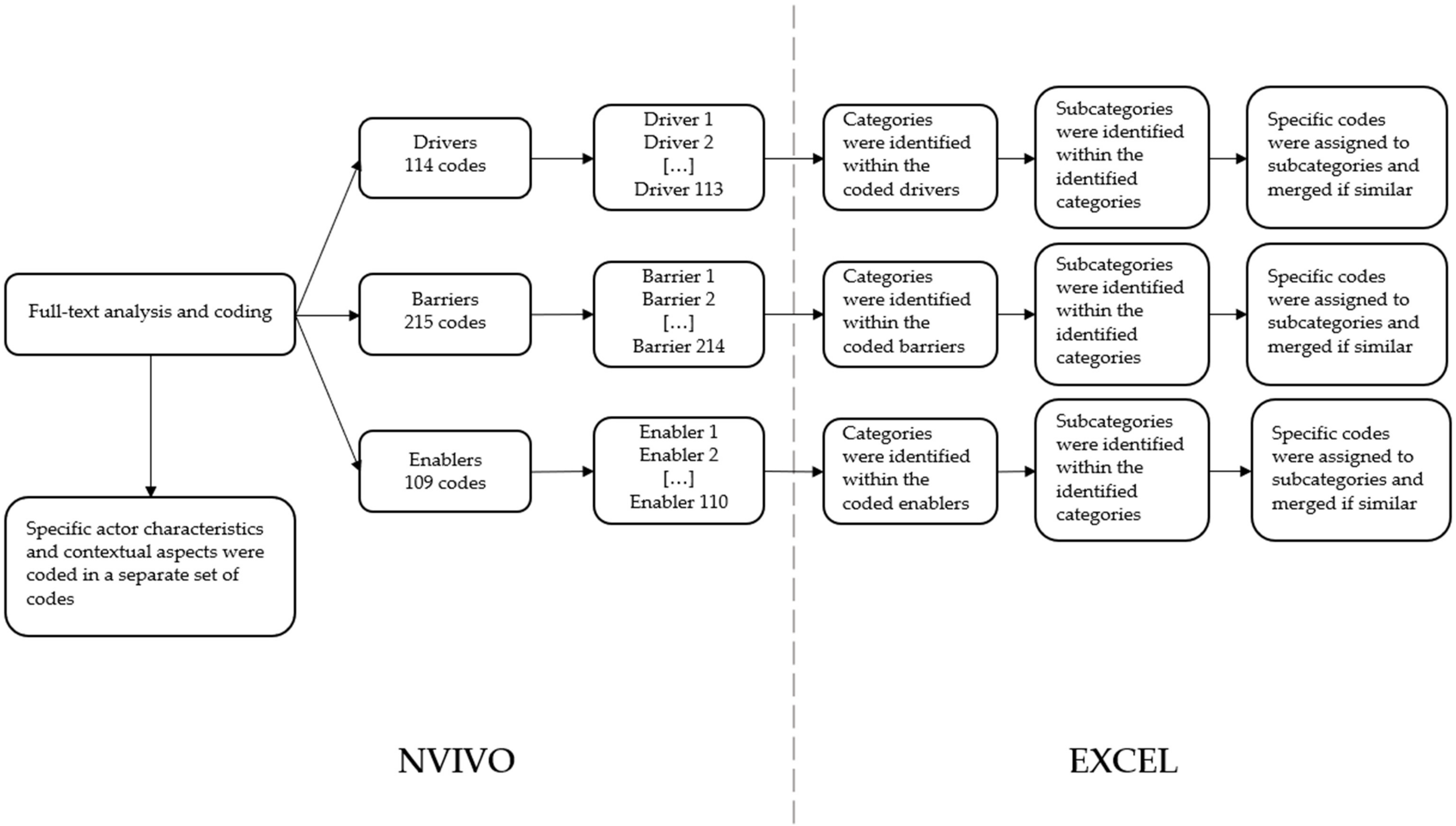

Figure 2. Illustration of coding and review process.

3. Results and Analysis

Section 3 presents the results from the literature review. Section 3.1 addresses the first objective of this article: to identify factors that influence actors' decisions to participate in symbiosis collaborations. The results from the coding and review process are presented to give a structured overview of the drivers, barriers, and enablers identified in the sample literature. In Section 3.2, the results are analyzed in relation to the second research objective of this article: to explore whether and how the perception and impact of these factors differ depending on individual actor characteristics and specific contextual aspects.

3.1. Identification and Categorization of Influencing Factors

By examining an extensive body of literature, the literature review resulted in three tables of drivers, barriers, and enablers that were identified as important factors impacting the formation of a symbiosis network. The drivers, barriers, and enablers were further clustered in the tables into the following six categories of factors that influence symbiosis collaborations:

1. Legal and political factors;
2. Economic and market-related factors;
3. Organizational and informational factors;
4. Techno-physical and geographical factors;
5. Community-related factors;
6. Environmental sustainability-related factors.

A compilation of the identified drivers, barriers, and enablers is presented in Tables 1–3. The columns in the tables are the six categories presented above. As described in Section 2.2, the drivers, barriers, and enablers identified in the literature were then further divided and merged into subcategories, where appropriate. These are presented in bold in the tables. Where factors are merged into subcategories, specific examples are listed to illustrate what constitutes the given subcategory. A full list of references supporting the findings in Tables 1–3 is presented in Supplementary Materials.

One interesting aspect that can be seen in Tables 1–3 is that some factors are presented as both drivers, barriers, and enablers. For instance, governmental support has been reported as a driver [18–21], barrier [22], and enabler [23,24]. In their case study, Taddeo et al. [20] find that full support from the local government would most likely act as a key driver in the formation of symbiosis collaboration. Local governments can take on a key role, identifying synergies and matching different actors, since they have an overview of the specific local conditions [25]. However, in certain contexts, too much governmental involvement can disincentivize collaboration [22]. This indicates that different actors perceive governmental support or involvement differently, depending on the setting of the symbiosis or the actors' own specific conditions and set of preferences.

Two additional factors reported as both drivers, barriers, and enablers are the composition of actors [20,26–28] and the size of the network [29]. For example, in some studies, heterogeneity in the network is reported as an enabling factor, as it creates flexibility and increases the probability of finding receiving partners [20]. Madsen et al. [26] also conclude that a diverse network can positively impact symbiosis collaboration since it becomes more likely that companies will find a matching partner with whom they can exchange resources. In contrast, several studies present the argument that diversity among actors may instead inhibit collaboration and create networks that are too complex and difficult to manage [27,28]. In addition, Lybaek et al. [30] point to the increasing complexity of involving too many actors with different sectoral affiliations. Cross-sectoral collaboration often implies that actors must conform to different legal frameworks, increasing the regulatory complexity of the network, which in turn may inhibit collaboration.

The examples above illustrate that the context of the network as well as the individual actors determines how different influencing factors are perceived. This indicates that both network and individual actor contexts need to be considered when researching topics related to the initiation and potential success of symbiosis networks.

Table 1. Drivers (a full list of references supporting the findings in Table 1 is presented in Supplementary Materials).

Legal and Political Factors	Economic and Market-Related Factors	Organizational and Informational Factors	Techno-Physical and Geographical Factors	Community-Related Factors	Environmental Sustainability-Related Factors
Policy - Direct policy - Indirect policy **Regulation** - Waste regulation - Environmental regulations - Changing legislation **Incentives** - Tax cuts - Landfill tax or ban - Waste disposal taxes - Price setting of resources - Property rights **Governmental support** - Guidance - Policy support **Monitoring** - End-of-pipe control - Source control **Certification** **Enforcement of regulation**	**Cost reduction** - Construction cost reduction - Low transportation cost - Reduction in input price - Reduction in operating costs - Cost of waste disposal - Financial pressure (carbon cost reduction) - Low-cost service **New business opportunities** - New products - Acquiring new clients - Byproduct valorization - Quality improvements - Positive marketing - Attracting new business - Diversification in products - High-value waste - Brownfield expansion - Waste or byproduct supply - Waste or byproduct demand - Additional revenue - Creating new areas of revenue - Increased turnover for the company **Increase in material lifetime** **Short return on investment** **Competitiveness** **Productivity savings** - Material productivity **Financial support** - Financial contribution from participating actors - Investment support	**Network composition** - New company entering industrial area - Building new partnerships with other companies - Self-organization - Local industry organization - Existence of support system **Employee-related factor** - Improved human resources - Staff mobility **Company culture** - Employee satisfaction **Trust and understanding** **Knowledge sharing** - Collective learning - Dedicated innovation teams **Information** - Transparency - Awareness of IS	**Geographic location** - Geographic isolation - Geographic proximity **Innovation and developments** - Technological readiness - Access to development of new technology - Research and technology developments - Technical obsolescence of existing process equipment - Improved quality/security of inputs - Diversification of fuel consumption **Waste diversion** - Land availability for waste disposal - Reduce load on own sewage system - Increased waste in new production technique **Monitoring and evaluation** **Infrastructure** - Pooling services **Shared logistics resources** **Risk reduction** - Reduced liabilities in storage of inorganic products - Cluster and supply security	**Regional development** - Contribution to community development - Community engagement **Job creation** **Local and regional studies of synergies**	**Emission reduction** - Pollution reduction - Reduction in GHG emissions **Improved environmental performance** - Corporate sustainability focus - Achievement of the environmental policy and targets of the company - Changing the company's business model to become more sustainable - Satisfaction of CSR requirements - Environmental benefits **Increased efficiency** - Eco-efficiency - Energy efficiency - Reduction in raw material use - Reduction in waste generation - Raw material substitution - Resource scarcity - Secure availability **Environmental awareness** **Waste diversion** - Safe destination for byproducts - Landfill diversion

Table 2. Barriers (a full list of references supporting the findings in Table 2 is presented in Supplementary Materials).

Legal and Political Factors	Economic and Market-Related Factors	Organizational and Informational Factors	Techno-Physical and Geographical Factors	Community-Related Factors	Environmental Sustainability-Related Factors
Government support - Lack of guidance in legislation - Difficulties in balancing governmental support between different industries - Lack of governmental support - Lack of policy support - Lack of legal enforcement - Too much government involvement - Lack of institutional support for integration, coordination, and communication - Lack of coordination between government and industry **Policy** - Direct policy - Indirect policy - Planning policy - Regulatory and political uncertainty - Changing legal requirements - Changing political landscape - Uncertainty in political support	**Competitiveness** **Core business focus** **Balancing benefits and costs within the symbiosis network** - Investment sharing - Unfair distribution of benefits and costs - Agreement on value of byproduct - Non-tangible benefits **Lack of resources** - Lack of time - Lack of capital/funding - Lack of investment - Lack of economic feasibility **Lack of economic incentives** - Low cost of waste disposal - Low-value waste - Low/long rates of return on investment - Low price on inputs - Revenue losses - Not reaching economies of scale - Competing with raw materials - Firm scale	**Administrative processes** **Conflicting agendas between/within actors** - Conflicting goals and interests - Ignorance of other businesses - Lack of agreement on waste solutions - Self-direction **Network composition** - Diversity among participating companies - Few large, established and financially strong actors - Large number of participants—difficult to manage and share information - Weak cross-sectoral cooperation and integration issues - Lack of anchor tenant - Changing industrial landscape - Existing structures - Lack of entrepreneur association **Trust and understanding** - Lack of trust and understanding - Confidentiality and commercial issues	**Technology, integration, and infrastructure** - Lack of technology - Availability of reliable recovery technologies - Technical integration difficulties - System fragility - Technical requirements - Lack of technical capacity - Dependence on non-renewable energy - Difficulties in having multiple energy suppliers - Aligning intermittent energy production - Lack of infrastructure readiness - Storage issues and lack of space - Lack of willingness to make changes to existing infrastructure **Geographic** - Lack of geographic proximity and nearby industry **Logistical issues** - Transportation issues - High transportation costs and dispersed production sites	**Community objections** **Lack of community awareness and understanding** **Regional development** **Uncertainty of effects on local population**	**Lack of commitment to sustainable development** **Lack of environmental awareness** **Lack of interest in eco-efficiency** **Community objections** **Lack of community awareness and understanding** **Regional development** **Uncertainty of effects on local population**

Table 2. *Cont.*

Legal and Political Factors	Economic and Market-Related Factors	Organizational and Informational Factors	Techno-Physical and Geographical Factors	Community-Related Factors	Environmental Sustainability-Related Factors
Regulations - Lack of regulations - Environmental regulations (general) - Waste regulations (general) - Regulations on selling waste - Quality requirements of waste - Waste minimization targets - Water and energy utility regulations **Lack of incentives** - Subsidies for primary material producers - Tax structures - Property rights **Ill-designed regulations** - Difficulties in tax reporting - Lack of legislative clarity - Ineffective market-based support instruments - Inflexibility in legislation **Permits** - Permit applications - Permits for industrial development	**Costumer requirements and acceptance** **Risk and uncertainty** - Market-related risk and uncertainty - Market price uncertainty - Unclear market status for second generation goods - Environmental and life cycle costs not reflected in market prices - Financial crisis (2008) - Financial uncertainty - Competitive risks - Risk of being cut out of benefits - Risk related to investment - Uncertainty about financial support **Increased costs** - Investment costs - Learning costs - Production costs - Transactional costs - Transport costs	**Work environment and employees** - Negative effects on workplace safety - Lack of motivation among staff - Cultural challenges - Reluctance to change - Lack of training to implement symbiosis collaborations **Lack of leadership** - Lack of intermediaries/facilitator - Lack of top management and informational head - Management practices - Information sharing - Lack of information and information sharing - Lack of openness and transparency - Information asymmetry - Poor communication **Lack of knowledge** - Lack of knowledge of residual streams and receivers - Lack of awareness of IS - Limited understanding of opportunities **External/internal risk exposure and uncertainty** - Unfair risk sharing - Seeking security - Risk associated with information sharing **Lack of cooperation and coordination** - Lack of internal coordination - Lack of cooperation - Lack of tools to organize collaboration and to monitor and maintain data - Networking difficulties - Lack of interest	**Risk and uncertainty** - Discontinuity - Uncertainty about waste supply and demand - Supply and demand mismatch - Infrastructural-related uncertainties - Waste quality uncertainty **Waste and byproduct utilization** - Waste composition - Waste quality - Small production volumes - Too small waste quantities - Implications of the waste hierarchy - Perceived quality of waste **Lack of monitoring and evaluation** - Absence of energy management systems - Lack of quantitative indicators - Lack of coordination mechanisms that collect and maintain data **Internal optimization**		

Table 3. Enablers (a full list of references supporting the findings in Table 3 is presented in Supplementary Materials).

Legal and Political Factors	Economic and Market-Related Factors	Organizational and Informational Factors	Techno-Physical and Geographical Factors	Community-Related Factors	Environmental Sustainability-Related Factors
Policy - Direct policy - Indirect policy - Bottom-up policy - Top-down policy **Incentives** - Subsidies - Tax on waste disposal **Governmental support** - Green procurement - Local government participation - Central coordination at the national level - Incorporation in national plans - Coordination between policy programs **Flexibility in regulations and guiding principles** - Tailored discharge standards - Harmonized legal frameworks - Clear waste and byproduct definitions **Guidance** **Stable political landscape** **Monitoring and evaluation** - Tools for assessment and evaluation	**Financial support and investment sharing** - Financial support from external funding bodies, e.g., investment funds or governmental support - Financial contribution from participating actors **Financial instruments** **Well-designed business agreements** - Long contracts - Equitable benefit sharing **Market-related factors** - Stable markets of participating companies - Markets for second generation goods - Stable pricing **Investment in R&D**	**Network composition** - Anchoring actor/committed actor - Established industry with local embeddedness - Suitable industry - Heterogeneity/diversity - Influential coordinators - Multiple partners - Strong industrial organization - Presence of local observatory - Self-organization **Cooperation and coordination** - Collaborative culture - Joint problem solving - Internal and external coordination - Network participation - Willingness to collaborate/participate - Bottom-up activities - Planning **Administrative instruments** - Platform for information sharing - Platform for networking - Advanced information technologies - Surveys	**Geographic location** - Geographic proximity **Access to technology** - Technical feasibility - Opportunity to link with cogeneration on site **Infrastructure readiness** - Infrastructure sharing **Shared logistics resources** **Flexibility in production** **Stable waste flow**	**Community engagement** **Public acceptance** **Society's demand for circular economy** **Well-functioning external communication** **Raising awareness**	**Corporate sustainability focus**

Table 3. *Cont.*

Legal and Political Factors	Economic and Market-Related Factors	Organizational and Informational Factors	Techno-Physical and Geographical Factors	Community-Related Factors	Environmental Sustainability-Related Factors
		Cognitive and social proximity - Shared strategic vision - Mutual interests - Close contact between partners - Personal relationships - Social conditions - Understanding of each other's businesses **Knowledge and information sharing** - Drawing on previous experiences - Knowledge and information exchange - Honesty - Trust - Raising awareness through education - Well-functioning internal and external communication - Feasibility study - R&D - Dedicated innovation teams **Long-term relationships** **Leadership** - Intermediaries or facilitators - Centralized cooperative authorities - Training by facilitators			

3.2. Actor Characteristics and Contextual Aspects

The review results show that the literature rarely focuses on the individual actor level perspective. This is in line with the observations by Walls and Paquin [15] that research on industrial symbiosis often lacks the individual firm perspective. Influencing factors are mostly reported at a network level or for symbiosis collaborations in general, instead of at an individual actor level. Furthermore, the focus of analysis in the literature seems to be on identifying influencing factors, determining their importance, and analyzing how they can be enhanced or downplayed for the entire IS network. Even though the actor level perspective is not clearly addressed in the literature, it is still often acknowledged that the specific context of the actors and the IS network need to be considered when analyzing factors that affect the collaboration [24,25,31].

By examining the selected literature, this review addresses the individual actor level perspective and identifies the following six characteristics and contextual aspects that appear to affect how drivers, barriers, and enablers are perceived by actors.

1. Sectoral affiliation and type of resource exchanged;
2. Company size and internal resources;
3. Actors' roles and responsibilities;
4. Geographic context;
5. Level of dependence, investment, and benefits;
6. Strategic vision.

These six characteristics and contextual aspects will be further explained and exemplified in the coming sub-sections.

3.2.1. Sectoral Affiliation and Type of Resource Exchanged

Companies in different sectors produce different types of excess resources, depending on the processes and materials used in manufacturing. These sectors could be monitored differently in terms of waste disposal/treatment and even regulated differently. As such, it is not surprising that the literature shows that influencing factors may affect actors differently, depending on sectoral affiliation and the type of resource that is exchanged [4,30,32]. For instance, Patricio et al. [32] conducted two case studies with a focus on small and medium-sized enterprises (SMEs) in the Västra Götaland Region of Sweden. The case studies consisted of two industries: mushroom farming and beer production. While Patricio et al. [32] did not distinguish the barriers and motivational factors at the individual actor level, they showed that there is a difference in how actors are affected by certain factors, depending on the byproduct in question. For instance, they identified that it was difficult to find a suitable receiver for some of the byproducts, while for other byproducts it was not economically viable. Domenech et al. [4] also found that the type of excess resource impacts the viability of a collaboration. Some resources may be associated with an undeveloped secondary market, while other resources are more established goods for secondary resource consumption. A resource that is not yet part of an established market may face more uncertainty in demand and pricing. The perception of risk and uncertainty concerning the viability of a resource exchange is likely to differ depending on the type of resource being exchanged. These findings are also supported by Watkins et al. [33] and Falsafi and Fornasiero [34].

Cross-sectoral affiliation may also result in companies having to conform to different legal frameworks, creating different conditions for the actors involved in the network [4,30]. This implies that a network consisting of actors from multiple sectors may experience a legislative complexity that is not easily managed. Lybaek et al. [30] emphasize the importance of focusing on the company/local level and on promoting bottom-up instruments to facilitate symbiosis collaboration. Henriques et al. [11] also observed the relevance of considering sectoral affiliation as having an impact on how influencing factors are perceived by different actors. Their literature review shows that there are substantial differences among different sectors in terms of what they report as barriers and enablers to symbiosis collaborations.

Given the examples and analysis above, sectoral affiliation and the type of resource exchanged seem to have a significant impact on how certain factors influence collaboration. Cross-sectoral networks need to navigate complex legal landscapes, since the different actors need to abide by different laws and certain resource types may challenge the economic viability of the network if they are not traded on established markets.

3.2.2. Company Size and Internal Resources

From an analysis of the sample literature, it is clear that the size of the individual actor affects how actors behave in a symbiosis collaboration. The case study by Madsen et al. [26] identified differences between a large company and a smaller company engaging in a symbiosis collaboration. There was a notable difference in the decision-making process between the two companies. The large company had a significantly longer chain of command, leading to a very long decision-making process, whereas the smaller company could quickly decide whether the symbiosis collaboration was a good idea and then put it into practice [26]. Contrary to these findings, Patricio et al. [32] show that it may be more difficult for SMEs to initiate symbiosis collaborations since they often have limited resources, lack knowledge, and are too focused on their core business. All SMEs included in their case studies reported limitations in time as an inhibiting factor for participating in symbiosis collaborations and their core business focus superseded participating in an IS network. These findings are also supported by Branca et al. [35], who found that SMEs experienced more limitations on investing in innovative initiatives. Large companies can, generally, make more investments than smaller companies [36], suggesting that it is relatively easy and less risky for large companies to invest and engage in IS. Madsen et al. [26] found that the size of the companies also determined how cautious they were about information sharing. The larger company was more hesitant to share information than the smaller company and used standardized contracts to safeguard their brand. Madsen et al. [26] also found that the smaller company might be put off by the complexity of the contract and may lack the expertise to evaluate the implications of such a comprehensive contract. This highlights the importance of considering power imbalances between partners, since this can affect the negotiation of contracts.

Päivärinne et al. [37] also point out that the size of the resource flow, and not merely the size of the company, is an important consideration. In their case studies, they find that certain actors only producing a small amount of the excess resource—heat in this specific case—do not find it reasonable and advantageous to participate in an IS network. The revenue stream generated from selling the excess resource is not enough to compensate for the time and resources committed to the IS project. These findings are also supported by Corder et al. [9], Colpo et al. [38], and Falsafi and Fornasiero [34].

These findings seem to suggest that company size is important. Although SMEs might enjoy a more fleet-footed decision-making process, they can lack the resources necessary for IS initiation. Government involvement and aid in the form of subsidies might alleviate some of these problems. Large companies, on the other hand, might not lack the resources but might make decisions about IS participation at a slower pace. Making that process quicker is perhaps more difficult, since there is a particular chain of command within the organization that needs to be followed. If large companies are potential participants in an IS project, it is probably wise to involve them at an early stage.

3.2.3. Actors' Roles in Collaboration

A prerequisite for an IS network is that there be multiple (at least two) actors involved and that an excess resource be exchanged between two or more parties. A network generally consists of at least one actor that supplies the excess resource and one actor that receives the resource. A network may also entail a facilitator that works to support the development of the collaboration. Clearly, the actors involved in the network have different roles to play in the symbiosis collaboration. The responsibilities of the actors have been shown to impact the perception of factors that influence participation [4,39]. For instance, Ji et al. [40]

show that a company's perception of different influencing factors differs depending on whether the company is a receiver or a producer of an excess resource. The producer of an excess resource is more likely to perceive valuable information leakage as a barrier than the receiver of the resource. It is considered more likely that the producer of the resource will disclose valuable information by sharing their waste. The receiver, on the other hand, is more inclined to experience uncertainty in waste supply as a barrier. This is explained by the fact that the receiver may be dependent on the excess resource in its production and thereby suffer more from a disrupted collaboration than the producing actor [40].

Noori et al. [19] support the notion that actors' roles in the collaboration clearly affect what drives them to participate. They show that driving factors differ between the individual companies and the facilitators (in [19] referred to as the cluster management). For the individual companies, economic benefits are among the most important factors, while eco-efficiency is an important driver for the cluster management. The facilitators of the networks, on the other hand, seem to aim for a collective improvement in eco-efficiency. This potentially shows some discrepancy between different levels of the symbiosis. At the actor level, participants are more interested in benefitting their own business, while the facilitators primarily look out for the good of the whole symbiosis network as opposed to individual business agendas. To achieve efficient and successful network participation, it is likely important that the facilitators create platforms for communication and collaboration.

The papers presented above illustrate that the roles of IS actors are important for the perception of the network collaboration, and, perhaps most importantly, the benefits that the different actors wish to achieve. The individual actors seem to need a viable business case associated with IS participation. If actors feel that their business might be adversely affected, they will likely be reluctant to participate. As highlighted by Prosman et al. [41], it is important that actors in the network gain an appropriate understanding of what their partners seek through the collaboration.

3.2.4. Geographic Context

Geographic context is a factor that is frequently mentioned in the literature as affecting IS collaborations. However, there are contradictions in the literature on the importance of geographic proximity. Several studies argue that long distances between partnering actors are a barrier and that long distances limit opportunities to exchange resources [20,42,43]. Furthermore, van Beers et al. [42] also suggest that geographic isolation may be a driver for IS collaboration. That is, an isolated cluster of industries may become more dependent on each other and instead solve resource exchanges within the isolated area. Prosman et al. [41] investigated whether geographic proximity is necessary for IS collaborations and found that geographic proximity can sometimes be replaced by other mechanisms in the collaboration, such as internal coordination and social proximity between partners. However, the importance of geographic proximity is, of course, very dependent on the resource to be exchanged and whether its transportation can be executed in a reasonably efficient manner.

Furthermore, there are several reasons why actors' geographic locations are likely to affect their perceptions of how they are impacted by different factors. Barriers reported in one geographic setting may differ significantly from those in another geographic location [33,44]. For instance, companies may have to conform to different regulatory frameworks depending on where they are located, which, in turn, may be more or less beneficial to IS network development [4,31,34,45–47].

Government support also varies depending on the geographic context. This affects how easy it is for actors to initiate symbiosis collaborations. In geographic contexts where government support is high, actors do not even have to consider this as an issue [48]. Moreover, Heeres et al. [22] found, when comparing IS initiatives in the Netherlands and the US, that there was a significant difference between how companies in the Netherlands viewed governmental support compared to companies in the US. The study suggests that US companies were more inactive and reluctant to participate in IS initiatives than the

Dutch companies, because they did not have a positive attitude towards local government involvement [22].

It appears that the perception of local government differs from one region to another. In the future, this might be a problem for the viability of large-scale implementations of IS networks. On top of that, different regional legislation could potentially inhibit the development of IS in certain areas. These issues cannot be resolved by the potential IS participants. Instead, they must be addressed by policymakers.

3.2.5. Level of Dependence, Investment, and Benefits

The perceived value of an IS collaboration will most likely vary between actors within the network. For some actors, the symbiosis collaboration may be a prerequisite for their survival, i.e., a "must have" collaboration. For other actors, however, it is potentially more of a "nice to have" collaboration, where the symbiosis collaboration improves their environmental performance and thereby their company brand [21,36,37,49]. The level of investment and the benefits received may also differ between partners in the network [35,43,50]. As such, equitable investment sharing and benefit sharing are vital to a successful collaboration [26,51], since unfair benefit sharing may risk discontinuity in the collaboration. An actor that benefits less than its counterpart may want to end the exchange or renegotiate the agreement [52].

In conclusion, an actor that is more dependent on the collaboration or has a relatively higher investment rate may have less bargaining power and end up with a less profitable agreement than its counterpart. For this reason, the level of dependence, investment, and the real or perceived value of the collaboration for the actors seem to be vital, since these factors may lead to an imbalance of power in the network and, consequently, in the negotiation of agreements.

3.2.6. Strategic Vision

Symbiosis networks generally consist of different types of companies, which have different internal strategic visions and goals. A network can consist of private companies, public authorities, and publicly owned companies.

A common strategic vision is reported as an important enabler in IS collaboration [37]. However, the strategic visions and goals of companies may differ depending on the ownership structure. Publicly owned companies may have to conform to goals set by the public authority that owns them, while private companies are freer to set their own strategic agenda. A study performed by Aid et al. [36] exemplifies how a publicly owned waste management company differs from a privately owned waste management company in how decisions are assessed. The publicly owned company experienced conflicting goals, since it was a direct subsidiary of a municipality and thereby needed to adhere to the municipality's social, economic, and environmental goals. These goals did not match their own business model of generating profit on large waste flows. The private company experienced no such conflicting goals and was freer to make decisions that better suited its business interests [36].

As noted in Section 3.2.5, a symbiosis collaboration may be an existential precondition for one of the actors, while for another actor it may only be a strategic business move to improve the business brand. Consequently, the strategic vision and goals of the individual actors may affect how they perceive and value the collaboration.

4. Concluding Discussion and Key Take-Aways

4.1. Concluding Discussion of Main Findings

As stated in Chapter 1, the aim of this review was to expand the understanding of the individual actor level perspective in symbiosis collaborations. By reviewing an extensive set of influencing factors that constitute drivers, barriers, and enablers to symbiosis collaboration, several actor-specific characteristics and critical considerations were identified.

This chapter discusses the importance and implications of these findings in terms of future research, theoretical and practical implications, and the limitations of the review.

Six principal categories were identified based on the drivers, barriers, and enablers found in the literature: legal and political factors, economic and market-related factors, organizational and informational factors, techno-physical and geographical factors, community-related factors, and environmental sustainability-related factors. Our analysis shows that drivers of, barriers to, and enablers of symbiosis collaboration vary greatly in the existing literature. The most interesting aspect of this is the fact that the same factor could be considered both a driver, barrier and enabler, depending on context. This implies that it will never be possible to consistently categorize each IS-related factor as solely a driver, a barrier, or an enabler. The review identified six specific characteristics that are especially important in terms of their influence on how actors perceive and are affected by certain factors. The characteristics and contextual aspects identified are sectoral affiliation and type of resource exchanged, company size and internal resources, geographic context, actors' roles and responsibilities, level of dependence, investment and benefits received, and strategic vision.

Through our qualitative analysis, we were also able to identify a set of recurring critical and underlying issues that are affected by the actors' characteristics and contextual aspects. Many of the characteristics and contextual aspects discussed are related to the same recurring issues. These issues are critical considerations that affect the actors' motivation to participate in IS. Our key findings in this review are the connections between actor-specific characteristics and the critical considerations. Table 4 presents these recurring considerations and the actor-specific characteristics to which they are related. These suggested connections and a discussion of our analysis are presented below.

Table 4. Three recurring critical considerations identified in relation to actor characteristics and contextual aspects.

Recurring Critical Considerations	Actor Characteristics and Contextual Aspect
Perceived business opportunity/business risk	Sector affiliation and type of excess resource Company size and internal resources Actors' roles and responsibilities Level of dependence, investment, and benefits
Inequalities within the network	Company size and internal resources Actors' roles and responsibilities Level of dependence, investment, and benefits Strategic vision
Regulatory and political setting	Sector affiliation and type of excess resource Geographic context

The first recurring critical consideration is perceived business opportunity/risk. The business risks revealed in the literature concern, e.g., uncertainty of the financial viability and uncertainty of market demand for secondary resources, which seem to be highly dependent on sector affiliation and the type of resource exchanged. The size of resource flows within the network is also important, as this is connected to how the companies assess the network's financial viability. Making large investments in time and resources might not make sense if the resource flow and the associated revenue streams are very small. Additionally, the risk an actor is willing to take depends on the company's size, the actor's level of dependence on and investment in the symbiosis collaboration, and the relative size of the received benefits. In addition, the actors' different roles in the collaboration also affect how they perceive business risk. One example is the differences between how suppliers and waste receivers perceive the risk of revealing sensitive information and waste supply uncertainty.

The second critical consideration revealed by the analysis is inequalities that may arise within the network, depending on different actor characteristics and contextual aspects. The issue of inequalities concerns power imbalances that may arise in business negotiations and investment and benefit sharing. Differences in company size and resource flow, the actors' roles in the network, and the actors' relative level of dependence and resource commitment to the symbiosis collaboration affect the (in)equality of the network. To successfully develop a symbiosis network, potential inequalities should be acknowledged and limited.

The regulatory and political setting is another critical consideration that recurs throughout the analysis of actor characteristics and contextual aspects. The setting that actors are exposed to is highly affected by both sector affiliation and the type of resource exchanged. If the network consists of actors from different industrial sectors, the individual actors might need to adhere to different laws. The geographic context also clearly affects the regulatory and political setting since legislation can differ between regions and countries. This means that certain areas are more suitable for IS network collaboration than others. When planning an IS network, it is important to assess whether laws and regulations allow for symbiosis collaboration.

In general terms, this study shows that differences between actors, regarding both their individual characteristics and their specific context, have a significant impact on decision making and how the actors perceive and are affected by factors influencing collaboration. The perception of the three critical considerations presented here is thus likely affected by the actors' individual characteristics and the specific context of the network. A potential actor's take on perceived business opportunity and risk, regulations, and potential inequalities of the symbiosis network will likely determine whether or not they are willing to participate in symbiosis collaboration.

From a theoretical perspective, revealing the characteristics and critical considerations presented in Table 4 could offer new ways of assessing and analyzing symbiosis collaborations, but potentially also conflicts in symbioses networks. Future research could also help verify these characteristics and critical considerations and eventually develop them into a framework that both practitioners and researchers could use to assess the soundness of the basis underlying symbiosis networks. They could also be relevant for practitioners working in or planning IS collaborations since they highlight the need to address certain concerns of individual actors, since the (potential) participants likely differ in their perceptions of business risk and other similar aspects. Expressed concisely: the findings of this paper could help both academia and practitioners develop a deeper understanding of successful IS collaboration through a better understanding of the perspectives of individual actors.

As previously noted, future research could investigate and verify the relations between the characteristics and considerations in Table 4; this investigation would perhaps be best performed through case studies on existing or planned IS networks. Other topics for future research are also identified. Future research could investigate methods of unifying risk perception in industrial symbiosis networks, with the goal of removing friction in this type of collaboration. Finding these kinds of methods could also result in less hesitation from potential symbiosis participants. Another possibly fruitful focus of future research could be on examining how and why inequalities within an IS network arise and how they should be addressed and handled to create a balanced and long-term sustainable collaboration.

4.2. Discussion of Limitations

This section briefly discusses some limitations of this study. Firstly, the literature included is primarily focused on existing or planned symbiosis networks. This implies that the analyses and results found in the literature sample are focused on drivers, barriers, and enablers experienced by the participants of these networks. There can, of course, be numerous potential symbiosis participants who never actually managed to successfully participate in a symbiosis initiative and who planned symbiosis collaborations that were never realized. In that sense, the papers included in the literature sample might suffer from something similar to survivorship bias; for the most part, only participants of successful symbiosis networks are studied. A second limitation is that all of the included papers adopt a case study approach, where a single case or multiple cases are studied. The over-representation of one particular methodology could imply that certain insights are not revealed by the literature sample. For instance, numerical or statistical evaluation of the drivers, barriers, and enablers and the outcomes of the symbiosis collaboration, both for individual actors and for the network as a whole, are not represented in the sample.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14094927/s1, Supplementary Material: References Supporting Identified Drivers, Barriers, and Enablers in Tables 1–3.

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Data Availability Statement: Publicly available datasets were analyzed in this study from Scopus and Web of Science. Data can be retrieved using the same search strings provided in this study.

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

Appendix A. Search Strings

In Scopus:

(TITLE-ABS-KEY (“*industrial* AND *symbiosis*”) AND TITLE-ABS-KEY (*driver*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*industrial* AND *symbiosis*”) AND TITLE-ABS-KEY (*incentive*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*industrial* AND *symbiosis*”) AND TITLE-ABS-KEY (*barrier*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*industrial* AND *symbiosis*”) AND TITLE-ABS-KEY (*obstacle*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*industrial* AND *symbiosis*”) AND TITLE-ABS-KEY (*enabler*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*urban* AND *symbiosis*”) AND TITLE-ABS-KEY (*driver*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*urban* AND *symbiosis*”) AND TITLE-ABS-KEY (incentive)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*urban* AND *symbiosis*”) AND TITLE-ABS-KEY (*barrier*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*urban* AND *symbiosis*”) AND TITLE-ABS-KEY (*obstacle*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))
(TITLE-ABS-KEY (“*urban* AND *symbiosis*”) AND TITLE-ABS-KEY (*enabler*)) AND PUBYEAR > *1999* AND (LIMIT-TO (DOCTYPE, “*ar*”))

In Web of Science:

(TS=(“industrial symbiosis”) AND TS=(driver)) AND (DT==(“ARTICLE”))
Timespan: 2000-01-01 to 2022-03-28 (Publication Date)
(TS=(“industrial symbiosis”) AND TS=(incentive)) AND (DT==(“ARTICLE”))
Timespan: 2000-01-01 to 2022-03-28 (Publication Date)
(TS=(“industrial symbiosis”) AND TS=(barrier)) AND (DT==(“ARTICLE”))
Timespan: 2000-01-01 to 2022-03-28 (Publication Date)

(TS=("industrial symbiosis") AND TS=(obstacle)) AND (DT==("ARTICLE"))
Timespan: 2000-01-01 to 2022-03-28 (Publication Date)
(TS=("industrial symbiosis") AND TS=(enabler)) AND (DT==("ARTICLE"))
Timespan: 2000-01-01 to 2022-03-28 (Publication Date)
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Timespan: 2000-01-01 to 2022-03-28 (Publication Date)
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Timespan: 2000-01-01 to 2022-03-28 (Publication Date)
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Timespan: 2000-01-01 to 2022-03-28 (Publication Date)
(TS=("urban symbiosis") AND TS=(obstacle)) AND (DT==("ARTICLE"))
Timespan: 2000-01-01 to 2022-03-28 (Publication Date)
(TS=("urban symbiosis") AND TS=(enabler)) AND (DT==("ARTICLE"))
Timespan: 2000-01-01 to 2022-03-28 (Publication Date)

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