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Green Social Networking Framework for Industrial Ecology Applications

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Abstract. This paper aims to review and analyse the role of social networking to stimulate the development of industrial synergies. In order to analyse how social media can contribute to achieving this goal and to ultimately reducing the environmental impacts of industry, this paper first presents a review of different models of the development of industrial symbiosis, as well as a literature review on Information and Communication Technologies for Industrial Symbiosis. Next, the new concept of Green Social Networking (GSN) is introduced as a novel application of Green IS, which aims to promote and develop cleaner industrial practices within industrial networks and regions. In order to present this new application of Social Media (SM), this paper analyses the most common functions of existing social media sites and highlights their potential contributions with respect to initiating industrial synergy. The practical contribution of this paper aims to introduce new options to stimulate information sharing in industrial areas and ultimately to facilitate the identification of industrial synergies. This paper also contributes to the definition of new information systems concepts, which practical usefulness must be studied and developed from a theoretical perspective.

Keywords: Green IS, industrial synergy, industrial symbiosis, sustainable development, social media, social network, Green Social Networking (GSN).

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1. Introduction

Industrial synergy can be considered as a form of eco-collaboration between two or more companies "in order to maximize the benefit of eco-efficiency" (Brooks *et al*., 2012). More specifically, it is defined as the operation of substituting or sharing the supply or treatment of a flow between companies (Bengoa, 2007), regardless of the nature of this flow (mutualistic or commensal) (Jensen *et al*., 2011). It differs from industrial symbiosis, which encompasses many such flows throughout entire industrial networks and regional economies. The concept of industrial symbiosis is described in many different forms across the literature and it is often associated with eco-industrial parks (EIP), eco-industrial developments, regional source synergies, circular economy and eco-industrial networking (Côté and Cohen-Rosenthal, 1998; Cohen-Rosenthal, 2003; Van Beers *et al*., 2007; Geng and Doberstein, 2008; Cardinalgroup, 2013). Specifically, an industrial symbiosis consists of exchanges between organizations in a given region or an industrial park, by-products , which may take the form of solid waste production, waste water or energy flow in order to increase the utilization of resources. It entails an industrial network, which can be developed either spontaneously (Chertow, 2000; Jacobsen, 2006) or through planning (e.g., as an EIP) (Chertow, 2007) regardless of its structure (Ashton, 2008). Such networks aim to achieve environmental goals and contribute to environmental sustainability. For the most part, economic incentives are the primary motivation for organizations involved in the creation of environmental benefits (Côté and Cohen-Rosenthal, 1998; Desrochers, 2004; Chertow, 2007; Duflou *et al*., 2012).

Exchanges between organizations are not restricted to material and energy flow, they can concern information and ideas about business practices (Mirata and Emtairah, 2005). Such intangible exchanges are essential for companies to help them find suitable business partners and share resources within a business community (Heeres *et al*., 2004)

In the globalized industrial sphere, Information and Communication Technologies (ICT) are crucial for the development of sustainable industrial approaches such as industrial symbiosis (Isenmann, 2009). The concept of Green IS is relatively new and, as such, is still poorly defined in the context of sustainable development. Some information system applications for industrial symbiosis currently exist, such as Prestéo (Société Systèmes durables), SYNERGIe (National Industrial Symbiosis Programme) and BRIQ (Centre de transfert technologique en écologie industrielle). However, to our knowledge, these applications do not include social media features. Furthermore, social media-style networking has yet to be integrated into the development of symbiotic partnerships. This paper proposes to address these issues.

2. Objectives and Methodology

This paper aims to analyze the potential role of social media to stimulate the development of industrial synergies. It should be noted that the terms "social media" and "social network" are used in a similar manner throughout this paper to refer to the idea of social networking. However, there is a difference between social media and social networks. The latter consists of technological tools that involve and facilitate entertainment, content creation, and interactions between people. It refers to all Web 2.0 tools (e.g., blogs, forums, social networks) that allow users to get in touch and share content with each other. The former refers specifically to the actual social connections between individuals, or at least the potential to reach individuals and form such connections. Social networks appear, among others, from the use of social media.

This distinction being made, this paper aims to identify the differences between various social media features and analyzes how these features might be implemented and used within information systems designed to facilitate the development of industrial synergies. In brief, through the analysis of the literature and the fields of IS, Green IS and industrial ecology, this paper aims to establish the potential benefits of initiating and promoting industrial symbiosis with the use of social media-style networks, in order to promote the development of the new field of Green Social Networking.

In order to do so, this paper first presents a review of different models of industrial symbiosis development. Then, it analyzes the literature on Green IS, and proposes an updated definition that conveys the added value that such information systems can provide tools for innovative green business development. Next, based on this literature and the analysis of the functions provided by social media, this paper proposes a definition of the new concept of Green Social Networking as a novel application for Green IS, which aims at promoting and developing cleaner industrial practices at the level of industrial networks and regions. This definition of Green Social Networking also entails a description of social media, particularly social networking, detailing their primary (e.g., sharing, collaboration) and secondary (e.g., advertising, linking) functions. This comprehensive analysis aims at highlighting the usefulness of social networking and the potential environmental applications of its various functions.

3. Industrial symbiosis around the world

The literature presents many case studies of regional industrial symbioses around the world such as the industrial area of Kwinana (Australia) (Van Berkel, 2007), the Rotterdam harbor and its industrial complex (Netherlands) (Baas and Boons, 2007), and Puerto Rico (USA) (Chertow and Lombardi, 2005). However, Kalundborg in Denmark remains the most cited example and is considered a model of industrial symbiosis (Jacobsen, 2006). There are two key reasons for explaining the past and continuing success of Kalundborg industrial symbiosis: these industrial partnerships are commercially viable and, the networked partners are located close to each other, which facilitates any form of material or energy exchange between them.

3.1 Two models of industrial symbiosis development

Industrial symbioses are typically organized within a community such as a city, for instance Kalundborg (Denmark), Kwinana (Australia), Guayama (Puerto Rico), Campbell (United States), Shenzhen and Ulsan (China), or a region, for instance the state of Styria in Austria, the Tianjin Economic Development Area in Binhai, China, the Rotterdam Harbor in the Netherlands, and certain UK industrial areas (Chertow *et al*., 2012). The analysis of such industrial symbioses shows that these exchanges, which are associated with environmental, economic and social benefits, are often propelled by local organizations and initiated by companies. The literature describes the concepts of industrial synergy and industrial symbiosis extensively, noting that the initiation and development of industrial symbiosis over time typically correspond to one of two development models (Chertow, 2007): a self-organized model and a planned model. Investigations and comparisons of these two models and their respective successes, failures and limiting factors have given rise to major debates. For instance, Lombardi and Laybourn (2012) revisited the initial definition of industrial symbiosis proposed by Chertow (2000), and denied the argument that geographical proximity was a key element for planned attempts at developing industrial synergy (in the form of eco-industrial parks). Beyond the need to understand contributing factors for the emergence of industrial symbiosis (either self-organized or planned), the need to better understand the initiation phase of this emergence is particularly relevant.

Self-organization refers to processes by which an organizational structure emerges on its own, without being led by an outside source. In business management theory, the existence of self-organized communities consisting of companies that share interests, protocols and infrastructure is well-documented (Miles *et al*., 2010). Their practices support collaboration among members. Self-organized communities manifest themselves in various circumstances, for instance to revitalize the economy of a community, to create joint ventures and achieve common goals for mutual gain, or to solve an environmental issue through an industrial symbiosis (Brooks *et al*., 2012). On the opposite, planned industrial symbiosis refers to processes where potential synergies are identified and initiated by a third party. This party generally uses structured approaches based on specific methods (e.g., COMETHE) and utilizes tools to analyze material flows within industry, such as:

- The Facility Synergy Tool (FAST), developed by the US-EPA, which is an access database connected to a geographic information system (GIS);
- Prestéo (Système durables), a web-based tool with limited (non-public) access, which incorporates a database of industrial flows favoring the closure of industrial flows and facilitating the identification of synergies;
- The ISIS (Industrie et Synergies Inter-Sectorielles) database, developed by the EDF (Électricité Réseau Distribution France) group; it only takes physicochemical aspects of flows into consideration;
- SYNERGiev, a system developed by the UK-based NISP (National Industrial Symbiosis Program); the system was developed as a support tool for facilitating industrial symbiosis programs within business communities; it is only accessible to the system's facilitators;
- The ISDATA project (Industrial Symbiosis Data Sources), which aims to structure data relevant to industrial symbiosis into one central repository.

Chertow and Ehrenfeld (2012) conceptualized the development of industrial symbioses as occurring in three stages: (1) sprouting, (2) uncovering and embeddedness, and (3) institutionalization. Self-organization can undoubtedly lead to the initiation and development of industrial symbioses, which can later be managed by a coordinating body, in line with this process (Chertow 2007). For example, in Kalundborg, environmental regulations triggered the development of industrial synergies as early as 1960 (Brings Jacobsen, 2006; Ehrenfeld and Gertler, 1997). Such a development results from a long process of evolution, even though it originated spontaneously (as opposed to the planned model). The success here is due to existing favourable conditions, such as the high level of trust between business leaders and an absence of competition (Duret, 2004).

While there were several studies on the success of self-organized industrial symbiosis (Chertow, 2007; Gibbs *et al*., 2007), other studies have identified mixed forms of evolution toward industrial symbiosis in businesses communities, arguing that this process does not occur spontaneously (Boons and Baas, 1997). Such studies emphasize that industrial symbioses can be effectively designed and promoted through national initiatives or policy instruments (Park *et al*., 2008; Van Berkel *et al*., 2009; Zhang *et al*., 2010; Shi *et al*., 2010). This planned (i.e., goal-directed) process of networking occurs when "*parties interact to achieve, plan, coordinate, or decide on their individual and collective activities*" (Paquin and Howard-Grenville, 2012). One of the most successful examples of the planned model is the UK-based NISP, which is a private sector initiative of the Business Council for Sustainable Development. This model considers the entire country as a eco-industrial park (Jensen *et al*., 2011) with the NISP being responsible for connecting its members, disseminating knowledge between them and ensuring a central focus on sustainable development (Lowe, 1997, Ashton, 2008, Costa and Ferraro, 2010).

3.2 Towards a hybrid development model of industrial symbiosis

Although the literature presents two opposite development models of industrial symbiosis, the reality is generally more complex. Industrial symbiosis partnership requires rather delicate cooperation. Trust, good personal relationships between leaders, broad community support and collaboration between pairs or groups of enterprises are important requirements for many functional eco-industrial parks, regardless of whether this partnership has been planned or developed spontaneously (Sakr *et al*., 2011). For example, in the Inter-Industrial Materials Flow Management Rhine-Neckar-Experience project (IMFM) in Germany (Sterr and Ott, 2004), an initial objective was to verify whether an industrial area could develop into an industrial symbiosis with the influence of an external catalyst (as opposed to a spontaneous initiation, as in Kalundborg). As a result, it appears that the regional level is the most appropriate for this type of symbiosis project because it enables a more substantial synergistic potential for the development of close loop flows. However, a disadvantage of industrial symbiosis initiatives at a regional level is that business communication and transparency are both more difficult to achieve. The outcome of this project also highlighted the need for tools, which provide a multi-platform communication forum within which experts and managers can create and foster mutual trust, and eventually coordinate business actions, while also allowing for the provision of reliable and inexpensive data to help companies stimulate this coordinated action.

Such tools are necessary for companies to exploit the potential of industrial synergy, for example understanding that their by-products and industrial waste are similar to those of neighbouring businesses, or that the waste of neighbouring businesses could be useful to them. More importantly, these communication tools are necessary to help companies realize that the challenge and responsibilities of waste management can be shared and that it is in their interests to work together on that issue.

Therefore, an approach to foster the development of industrial symbiosis would be to use information technology to enable companies to share some level of information that would allow them to identify and pre-analyze synergy opportunities. Such an information system could support companies to jointly solve their industrial waste and by-products issues. It could also promote planned regional initiative by actively identifying companies that could be relevant to such initiatives. Such an approach of industrial symbiosis development would be deemed hybrid as it has characteristics of both the self-organized and planned approaches to industrial symbiosis development.

Beyond the formation of a symbiotic business community, it is still important to consider, at the micro level, the development of a single industrial synergy between two businesses. A “simple” exchange consists of the establishment of a link between two companies, in which both are aware of the benefits of their cooperation (Heres *et al*., 2004). The development of such a link can in turn affect other companies and stakeholders (Meneghetti *et al*., 2012). For instance, the synergy and symbiosis projects conducted by the *Centre de Transfert Technologique en Écologie Industrielle* (CTTEI)[1] show that when a company has developed a synergy, it also develops the capability to move forward with other similar initiative and create further opportunities for symbiotic development.

Table 1 outlines both the planned and self-organized symbiosis development scenarios, as previously discussed. A hybrid scenario is also presented in order to account for symbiosis with both origins. Note that the information in Table 1 only pertains to the initial phase of a synergy project. Therefore, only a preliminary feasibility study is included to identify unrealistic synergy opportunities that can easily be screened out. However, because synergy projects usually require investments (Grant *et al*., 2010, Duflou *et al*., 2012), a more robust economical and technical feasibility study would need to be carried out once a first contact is made.

All three scenarios follow the same general steps: (1) acknowledgement of a need; (2) identification of potential synergies; (3) preliminary feasibility check; and (4) contact between companies. The hybrid scenario is a mix of both the planned and the self-organized scenarios. A third-party may sometimes be involved, which is an organization whose presence is mandated by the needs of direct (i.e., potential partners) or indirect stakeholders (e.g., cities, industrial associations, or other forms of authority) in a synergy.

[1] http://www.cttei.qc.ca/realisations_projets_e.php

Table 1: Symbiosis development scenarios

Steps of a scenario	Planned scenario (top-down)	Self-organized scenario (bottom-up)	Hybrid scenario
Acknowledgement of a need	Acknowledgement of a need to manage waste or by-products by an organization within a given area. This need is not necessarily acknowledged by the producer of the by-product.	A company acknowledges its need to manage or acquire another company's waste or by-products. By-products are seen as a potential feedstock for another company’s processes.	Identification or acknowledgement of a need to manage wastes or by-products by an organization, which may be the producer or the potential user of the by-products, or a third-party.
Identification of potential synergies	Identification of potential synergies by a third-party mandated to improve the management of the wastes or by-products.	Identification of one or many potential synergies by the by-product producer or the potential by-product user within a given geographic area.	Identification of one or many potential synergies by the producer, the potential user of by-products, or a third-party, within a given geographic area.
Preliminary feasibility check	Preliminary verification of the feasibility and interests of both the producer and the potential user by the third-party organization.	Preliminary verification of the feasibility by the company with the need.	Preliminary verification of feasibility and interests from potential partners; this process is carried out by: • the producer or potential user of by-products (if synergy is to be more self- organized); • a third-party mandated to develop synergies (if synergy is to be more planned).
Contact	Contact between the companies is initiated by the third-party.	Contact between the companies is initiated by one of them.	Contact between the companies is initiated by one of them or a third-party.

Table 1 highlights an explicit understanding of the needs is important for the initiation of a partnership; parties must acknowledge their mutual interest. This generally shows itself through a company recognizing a way to improve a specific inefficiency. This inefficiency or problem is here forth referred to as the "need". Such a need becomes the basis of discussions about any industrial synergy plans or opportunities for identifying potential synergy. It should be noted that these needs are not necessarily acknowledged explicitly by direct stakeholders, and in the planned scenario, they can be identified or monitored by a third party.

The next developmental step of industrial symbiosis, according to Grant *et al*. (2010), is the identification of synergy opportunities, which can occur through three possible means: (1) the development of new processes that transform by-products into usable resources or products (which is usually a long-term approach); (2) the replication of successful synergies by similar organizations elsewhere; and (3) the matching of input and output between companies. In all three synergy development scenarios presented in Table 1, these means can be instrumental. However, in the case of a planned approach, a third-party can develop the expertise or specific tools to implement the second and third means (i.e., replication and input-output matching).

Another important aspect in the identification of synergy opportunities is access to information. Again, a third party can be instrumental for gathering such information in order to either replicate existing synergies or improve matching between businesses. In the case of self-organized symbiosis, potential partners must become aware of their complementarity on their own. Therefore, in order to facilitate the development of industrial symbiosis on a self-organized basis, organizations must reduce the “mental” or “psychological distance” between themselves and potential partners (Jesen *et al*., 2011).

Once a synergy opportunity is identified, it is necessary to conduct a preliminary feasibility check in order to eliminate unfeasible matches. Note that the identification of opportunities and their feasibility check can be carried out in a more or less simultaneous manner, depending on the intensity of the preliminary check.

Finally, once a feasible synergy opportunity is identified, the direct stakeholders must confirm the feasibility as well as their mutual interest. In order for the synergy to flourish and develop, they must develop trust over time (Erkman, 2001; Lambert and Boons, 2002; Gibbs, 2003; Mirata, 2004; Murphy, 2006; Ashton, 2008; Sakr *et al*., 2011). The subsequent phases of synergy development are outside the scope of this paper, and may be considered along the lines of more traditional forms of business development. The next sections of this paper deal with these steps of initiating industrial synergy and their links to the concept of Green IS.

4. Green IS

Green IS usually refers to an information system that is used to achieve an environmental objective (Dedrick, 2010). There are still ambiguities with respect to what exactly constitutes a green IS (Ijab *et al*., 2010). This section reviews academic discussions in order to propose a more specific definition of Green IS. Since there is a marked difference between IS and IT (Boudreau, Chen and Huber, 2007), this study leaves out the Green IT literature as it focuses on hardware aspects of information systems, such as servers and computers energy consumption, and life cycle analysis of their components and sub-systems. This paper focuses on green software systems.

4.1. Redefining the role in Green IS

This section aims to explore the new roles of green information system (Green IS), which has increasingly become more than storing, transmitting and processing information. The need to redefine the role of IS in the sustainable development domain (referred to as Green IS in this paper) is ingrained in literature. As Ijab (2010) stated "Although the Green IS construct has become in common use, it is not well defined". The common definition of Green IS is the use of

IS in order to achieve specific environmental objectives (Dedrick, 2010) by encouraging individuals and organisations to adopt sustainable behaviours (York *et al*., 2009) called eco-sustainability (Gholami *et al*., 2013) through automation and transformation of products, business processes, business relationships and practices (Chen *et al*., 2008 and Melville, 2010). Brooks *et al*., (2012) in their definition encompass four elements: technology, human aspect, organizational mindset and culture.

Basically, in this paper, we argue that the role of Green IS includes three main roles, namely: storing, retrieving and presenting information; supporting decision-making; and coordinating green initiatives. These roles, when combined, could set the stage for initiating or promoting industrial ecology in an innovative way.

The first basic role of Green IS is to provide, on the one hand, functions such as saving, storing, transforming, and publishing data (i.e., inputs) emitted from one or several sources. On the other hand, IS provides functions to transmit this data to one or several destinations. This is the foundation of the other functions of Green IS. It allows companies to monitor and control specific production indicators, which in turn enables them to assess specific emissions, their trends, and to carry out simple data analysis. Although these functions are common to any IS in general, issues related to semantic and data modeling must be address in order to enable information sharing between organizations across regions and countries (Grant *et al*., 2010). In the context of industrial ecology, this is particularly important for the sharing of good practices and knowledge dissemination.

The second role of Green IS is to support decision-making. It builds on the previous functions in order to provide advanced tools of data analysis. These functions include environmental impact assessment tools (see Cucek, *et al*., 2012 for a recent review) and eco-industrial park design tools (see Boix, *et al*., (2014) for a recent review). These tools often embed specific knowledge in the form of information and mathematical models and indicators (e.g., impact indicators, environmental footprints, cost models, flow models). They can also exploit the knowledge of past analysis, impact studies, and best practices in order to provide impact and performance estimations, forecasts or recommendations. Such tools are necessary to assess the cost/impact trade-off of industrial synergy, as well as their most cost effective configurations.

Finally, the third role of Green IS aims to coordinate interaction between actors in order to support green initiatives. Such initiatives often require the involvement of several actors. Industrial synergies and symbiosis are perfect examples. In order to support such initiatives, Green IS can provide simple functions such as a shared virtual environment to coordinate appointments and exchange information. It can also provide more advanced functions in order to collaborate on complex projects, such as green product development. In the specific case of industrial ecology, a Green IS can provide a space to exchange information and experience, but more importantly, a means to initiate and coordinate the design of industrial synergies and symbiosis. The industrial ecology approach is an evolutionary process that usually takes time. It is therefore vital to ensure a good coordination between the actors, including companies, governments, municipalities and economic development agencies. It is especially important when the links between these actors are weak or nonexistent. This coordination requires a swap space to allow trust, closeness and communication. It must promote face to face between network members. Green IS can reduce transaction costs through the centralization of information, but most importantly, it can reduce the time to search for potential synergies.

4.2. Social IS functionalities for industrial synergy and symbiosis development

In the context of industrial ecology, Grant (2006; 2010) examined several IS tools developed between 1995 and 2000 in order to identify synergies in the context of industrial clusters, and found that these tools suffered from high start-up costs. They were also generally too complex, as they were designed for specific individual users, not organizations’ end users. Furthermore, they were not designed to facilitate actual cooperation or integration between potential business partners. Their specific objective was only to support the identification of potential industrial synergies. They were often based on a Geographic Information System (GIS), which stores and retrieves information to find resources (e.g., wastes, by-products) based on geographical proximity, or on the premise of searching through a directory with a structured list of classified resources. These IS applications were mainly used to characterize and analyze the flow of materials and energy (i.e., the industrial metabolism) in an industrial system. In other words, they can assist in the search for synergy opportunity, but their access is generally limited to specific users through an online portal or licensed access. These types of applications are part of a new class of IS applications dedicated to solving environmental issues, which is referred to as *Environmental Informatics* (Pillmann *et al*., 2006; Isenmann *et al*., 2009).

Along the same lines, the definition of Industrial Symbiosis by Lombardi *et al*. (2012) shares similarities with that of Watson *et al*. (2010): "[engaging] diverse organisms in a network to foster eco-innovation and long-term cultural change. Creating and sharing knowledge through the network yields mutually beneficial transactions for novel sourcing of required inputs, value-added products destinations for non-outputs, and improved business and technical processes". This definition clearly emphasises the importance of knowledge sharing in a context of eco-innovation and mutual benefits, which, in turn, highlight the social nature of industrial symbiosis.

Similarly, self-organization in the context of knowledge processing (Gutounig, 2011) through social media such as Wikipedia, bookmarking sites (which allow users to save links on a public website) and crowd sourcing (which allows companies to outsource certain functions by soliciting contributions from the online community rather than from their employees or suppliers), and self-organization in the context of industrial symbiosis share basic principles with respect to generating, distributing and applying knowledge. In particular, there is an overlap between some elements of industrial symbiosis (i.e., Organizations, network, creating, sharing and applying knowledge) and certain components usually found on social networking sites (i.e., social actors, profiles, social relations and content). These overlaps raise the following question: what role social media can play in supporting the initiation and development of industrial symbiosis? This question is addressed in the next section.

5. Current role of social media

Social media (SM) aim to simplify communication, data sharing and collaboration between individuals and organizations (Edosomwan, 2011). Bolotaeva and Cata (2010) define social media as tools dedicated to the creation of communities between online users who share common interests, activities and goals.

Based on this general definition, this paper specifically defines social media as web-based tools with social functions available to web publishers and/or site owners, which are run by a community through a desktop or a mobile interface. In more practical terms, it is a technology with well-defined recreational and social functions with operations fuelled by various data (e.g., images, video, text) being shared or exchanged. This definition primarily emphasizes the communication technology aspects (exchange and sharing) and informational aspects (i.e., data), which contribute to forming social networks. Because of similarities between social networks and industrial symbiosis, since both require exchange and sharing of data, this paper makes the assumption that SM could be useful for building synergies between organizations. In this section, four specific functions of SM that are relevant for the initiation of industrial synergies and symbiosis are analyzed: (1) the promotion of learning from each other; (2) the promotion of information sharing; (3) the building of relationships; and (4) the facilitation of community coordination.

5.1 Promotion of learning from each other

One of the challenges in the development of industrial symbiosis lies in the promotion of the basic principles of industrial ecology. Beyond the need to efficiently manage the disposal of industrial waste, companies must first perceive their waste and by-products as potentially valuable assets and not as problems that must be dealt with. Hence, the sharing of good practices and experiences to be derived from industrial ecology can positively contribute to changing the perception these organizations have of their waste products.

Focus groups on social networks have shown that they can promote the development of learning-based communities, in which members share explicit or implicit knowledge and learn from other members (not necessarily just their own contacts). This sharing of knowledge may include anything that members believe to be true or relevant about the world. This knowledge is what people use to make decisions or solve a problem. It can be explicit and learned through formal means, or implicit, representing knowledge that members have experienced and learned through practice over time. In particular, because implicit knowledge is generally related to an individual's experience, the use of a point of reference that aggregates many members and experts, such as a social media web site, increases the likelihood that someone's personal experience might contribute to solving somebody else's problem. In other words, social media web sites allow their members to share their problems, solutions and experiences. They allow them to find solutions to problems for which other members have already found solutions. This kind of cooperation on social media forums allows experts to diffuse their expertise and contribute to the building of their online reputation. It also supports passive (i.e., non-contributing) members to take advantage of exchanged knowledge. Such SM tools overall allow for knowledge to be capitalized upon through the process of sharing. There exist many focus groups in the domain of industrial ecology and symbiosis; Table 2 presents a few of them.

Table 2: Focus groups in industrial ecology and sustainable development

Platforms	Focus Groups Names	Subjects
LinkedIn	ISIE Group	Industrial ecology
	Industrial symbiosis	Industrial symbiosis
	Sustainable development	Sustainable development
	ISDATA	Data integration and sharing
Facebook	Industrial Ecology Students and Graduates	Industrial Ecology
	Industrial Ecology Chalmers 2013	Industrial Ecology
	Green Information Technology	Green IT
Tumblr	Modern industrial ecology	Industrial Urban Ecology
Viadeo	Industrial opportunity (in French: Opportunité industrielle)	Industrial synergy
	Eco-project (in French: Éco-Projet)	Ecology and sustainable development
	Industrial ecology (in French: Écologie industrielle)	Industrial ecology
Youtube	Methods in Ecology and Evolution (channel)	Industrial ecology
	Sustainable Development UN	Sustainable development
Blogs	Interfacecutthefluff	Sustainability
Twitter	IntlSynergies & NISPnetwork	Industrial ecology

5.2 Promotion of information sharing

Information differs from knowledge because it cannot be directly used as a rule or a guideline to make decisions. It can take the form of observations, which have not necessarily been assimilated or formalized into knowledge. It is the raw material of knowledge creation, which can be used to make decisions and solve problems. Like knowledge, information can be shared, stored and retrieved in a structured manner, and consulted in order to contribute to solving a problem.

For instance, in the context of healthcare, Boyer (2011) pointed out the uses of social media spaces for exchanging and communicating information (and knowledge). By doing so, the author described ways in which people can use social media to share their concerns about medical diagnoses with geographically distant friends and families. Along the same lines, Sharp (2011) described the example of a clinic, which adopted social media platforms to promote the sharing of patients' feedbacks. Instead of relying on more standard forms and reports, this clinic used Facebook, Twitter and YouTube to engage patients and gather their feedback.

Information sharing can also take a more specific form, such as collaborative work on shared documents or discussion forums, which trace the information exchanged over time. For example, groups on LinkedIn (equivalent to “hubs” on Viadeo) such as "International Society for Industrial Ecology" or "industrial symbiosis" allow users to learn from and network with other professionals. These groups provide a valuable way for professionals to monitor and keep up to date with global developments in the field of industrial ecology. They allow members to ask questions, get feedback about relevant events, and send invitations to events. They can serve as a forum for resolving business concerns. They can also help researchers to obtain unpublished information.

Other examples of platforms that facilitate the sharing of information are video sharing sites like YouTube and Dailymotion. On these platforms, anyone can create a channel (WebTV), on which it compiles a range of videos. Other users may then interact with and comment upon these videos. Although they are not really exploited for business purposes, such channels could play useful roles in promoting concepts of industrial ecology, as well as for sharing experiences of industrial synergies.

5.3 The building of relationships

Another important aspect of social media is their ability to build relationships. The basic principle of social media utilization is similar across different platforms. They typically allow users to create their profile consisting of their personal information, interests, and a photo. Users are then asked to invite friends, or acquaintances, to join their network, or to form connections with other users of the platform. Over time, users build up a network of contacts. Social media platforms could thus be valuable to businesses aiming to operate in an environmentally sustainable manner. They provide an effective approach for building a network of contacts, which possesses shared interests in industrial ecology and in the creation of industrial synergies, or generally, contacts which have similar problems.

Specific social network functions that support the building of relationships with second and third level contacts (e.g., LinkedIn), or more specifically with "compatible" contacts, might be useful for supporting the emergence of industrial symbiosis. For example, the "import contacts" function, allows one to import contacts from a user's email account and add them to his/her network on a social media site. The implicit function of contact filtering is also useful for building relationships. It is generally based on heuristic rules that quantify the level of compatibility between unrelated users (for example by calculating the number of shared contacts). In the case of industrial synergies, this compatibility is more complex to evaluate, as it is dependent on private information, but this information could be shared with a neutral and trusted third-party, such as through a social media platform. Along this line, a social media platform with access to a think tank of experts and researchers could similarly contribute to fostering relationships between organizations and the sharing of knowledge and information.

5.4 Facilitation of community coordination

In social media, community coordination can take the form of a content management function, executed by a person whose primary role is to encourage discussions and potentially contribute to knowledge and information sharing. It also serves to keep exchanges on a social media site within a specific framework of content and ethics. In the context of industrial symbiosis, this function is similar to that of a facilitator (sometimes called a champion) (Sakr *et al*., 2011; Meneghetti *et al*., 2012). Since the notion of champion is used frequently in project management literature, and because industrial symbioses are not necessarily planned (top-down), the term "content and community manager" is preferred in this paper. It refers to community managers or facilitators who work with social networks and in social media disciplines.

A community manager's primary function is the development and management of organizations' presence on a social network. These managers take care of keeping discussions focused on a particular topic, while ensuring the confidentiality of business information that is exchanged. In addition to this rather passive role in the community, a manager can also take a proactive role in order to create links between organizations, therefore contributing to initiating industrial synergies. For instance, in the UK-based NISP initiative, there are regional facilitators who use specific tools such as SYNERGIe to identify and analyse synergy opportunities. A manager is a neutral actor with knowledge and experience in industrial ecology and industrial synergy initiation. S/he has access to private or confidential data and information. Consequently, the function of such a facilitator, together with the use of a social media platform, can be instrumental allowing for the emergence of an industrial symbiosis within a virtual business community.

5.5 Limits of current social media

Among the four main functions of social networks, as illustrated in Table 3, the sharing of information and knowledge are the most common in green social media. However, other functions such as the building of relationships, which is commonly used in social media such as Facebook and Twitter, are limited to the sharing of specific information in the case of green social media. Unlike general SM platforms, social networks used for industrial synergy initiation would primarily be interested in functions, such as the storage, the retrieval and the analysis of confidential business data and information, as well as more advanced functions, such as data filtering and analysis, and potentially even decision support functions. The main role of these social functions is to gather data (e.g., browser, location, IP address, search queries, profile information) through different methods of getting data (e.g., third parties, cookies, log data, device tracking technology) in order to use and analyze these data to provide synergy solutions, send information to companies, or notify. However, the taxonomical classification of resources remains a challenge to their implementation because they require a common language to produce relevant search result (Grant *et al*., 2010).

Similarly, the social media function of community coordination has not yet reached a level that is appropriate for promoting the bottom-up emergence of industrial symbiosis. As demonstrated by the NISP initiative, coordination is a function that is mostly carried out by facilitators who act as a catalyst between potential partners. Indeed, the presence of an intermediary between manufacturers usually prevents the development of their mutual relationships, at least in the early stage of synergy development. This is the case in several existing platforms (e.g., BRIQ, Second Cycle), in which the owner of platform is directly responsible for most of the publishing, search and exchange processes, and the coordination to support the emergence of industrial symbiosis. These kinds of application do not directly benefit companies and do not really exploit the information exchanged, tough they reduce search costs for sellers and buyers of waste, helping to match the needs of both parties and facilitating the resulting transactions.

In order to explore further the potential of social networking to support the initiation of industrial symbiosis, the next section introduces and discusses specific social media functions, and proposes a list of functions that may best contribute to fostering interactivity and the building of business relationships.

Table 3: General functions of existing social media platforms and IS applications dedicated to industrial synergies

	Platform	Share knowledge	Share information	Build relationship					Coordination			
				Mode		Purpose			Nature			
				SO: self-organized	P: planned	IKS: information and knowledge sharing	ISI: industrial synergy initiation	ISP: industrial synergy promotion	IC: interest compatibility	OC: opportunity compatibility	IOC: input-output compatibility	Q/AC: question answer compatibility
IS dedicated to industrial synergies	Prestéo	X	-		X		X				X	
	SYNERGYe	X	X		X	X	X			X	X	
	BRIQ	-	X		X		X				X	
	Second Cycle	X	X		X	X	X			X	X	
SM dedicated to sustainable development	Carbonrally	X	X	X		X			X			
	Zerofootprint	-	X		X	X			X			
	MakeMeSustainable	X	X		X	X			X			
	Celsias	X	X		X	X			X			
	Change.org	X	X		X	X	X		X			
Generic SM	LinkedIn, Viadéo	X	X	X		X	X	X	X			X
	FaceBook	-	X	X		X		X	-	-	-	-
	Flickr	X	X	X		X			-	-	-	-
	Delicious	X	X	X		X			X			
	Answers_wiki	X	X	X		X						X
	Youtube	X	X	X		X		X	-	-	-	-
	Photobucket	X	X	X		X			-	-	-	-
	Ask	X	X	X		X						X

6. New functions for Green Social Networking

We argue that the generic functions (i.e., building relationship and community coordination) of current IS applications dedicated to industrial synergies are not sufficient to support several aspects of the development of an industrial synergy. In order to show how particular social functions might work in this context, this paper considers Green Social Networking as a set of green IS applications (yet to be developed) with the purpose of supporting the emergence of industrial symbiosis and collective environmental initiatives. In order to define general guidelines for the development of such applications, this section first discusses the basic functions of SM (e.g., walls, circles, smart lists - note that the names of these functions vary across platforms) that can contribute to this goal.

6.1 Social media functions to support of sustainable development

The service functions (e.g., content management, discussion) of SM are changing rapidly through continuous improvements and new designs. Despite such changes, the main social features these functions aim to exploit remain the same: promoting the discovery of similarities, complementarities, and shared interests between different users/parties. An understanding of how the functions of SM enable such discoveries and contribute to providing services to communities is necessary to take advantage of SM to create professional communities, which could ultimately be useful for initiating industrial synergy and developing knowledge (Grant *et al.*, 2010). In particular, the study of the functions highlighted in this section aims to guide the design of information systems that will support a hybrid development of industrial synergies, accommodating the spontaneity of individual companies as well as the coordination of industrial synergy by third parties.

SM functions can be classified into two categories: primary and secondary. Primary functions are related to information exchange and discussion. Exchanging and discussing are the basic features of SM, even if different platforms use a different vocabulary to describe these processes. For instance, similar information exchanges might happen through "sharing" on Facebook, "retweeting" on Twitter or "riffing" on So.cl. Secondary functions of SM, which are sometimes referred to as "accessories", are used to build upon and complement primary functions and include functions such as advertising and event creation. Secondary functions also serve to improve users' experiences before the social processes of sharing and exchange (such as the process of opening an account), or to generate revenues (through advertising). Such functions are secondary because they do not directly relate to the basic principles of social networks: the existence of contacts and the connections that form between contacts (Barnes, 1954).

To attract and retain members, a social network platform must support them through primary and secondary functions that are useful to users' daily operations, allowing them to establish effective communication channels through which they can reach each other. This section proposes a classification of primary and secondary functions, and analyzes them with respect to their potential contributions to the development of industrial synergy.

6.1.1 Primary functions of a social media platform

In this classification framework, there are four types of primary functions: information, exchange, discussion, and legal.

Information function: the strength of a social media platform and its community lies in its ability to present and communicate information on a regular basis and to generate visits by users. SM platforms organize information in different forms according to the type of community they are catering to. For example, the social network *Digikaa* has developed a "social portfolio" function. Here, users can be connected to a project on which they are working, or have previously worked, and add projects directly to their profile in order to improve their profile and experience. The idea is to aggregate user's professional experiences through a list of projects.

Beyond the simple transmission of information, the structure through which information is presented, organized and linked to other information is designed with the user experience in perspective. For instance, a user can tag companies as well as other project participants in a particular project, and then the information is automatically relayed onto these other participants' resumes. Similarly, the *Google+* platform includes a function called “Spark” which provides a stream of information, which constantly updates itself on topics of interest to users, including articles and videos that appeal to other users. Users can read, view and share this information with their contacts.

Exchange function: as mentioned above, the strength of a social media platform is its ability not only to present (i.e., make someone aware of something for a purpose), but also to communicate and exchange information (i.e., diffuse, transmit information without specific intention). The exchange function is thus characterized by the communication of content that a person or organization wishes to share with other users. This includes articles, opinions, reflections, white papers, promotions, and professional experiences. Users may also share content that they do not necessarily like or agree with. A noteworthy aspect of the exchange function is that such exchanges of content can affect the reputation of each entity involved in the exchange, contributing to building individuals' "e-reputation".

Discussion function: this function extends the information and exchange functions, allowing users to publicly communicate with other social network members, through commenting, the demonstration of an expertise or the communication of an opinion. This function also incorporates users’ reactions to content shared by others. The “comment” or “reply” functions typically constitute a major part of the discussion function. This function is implemented through hubs, groups, discussions or questions (e.g., discussions on Viadeo). Google+ provides several examples of this function, such as video-bubbles on which users can click to engage in discussions on videos or to organize a group discussion within a circle of users.

6.1.2 Secondary functions

Secondary functions are SM functions that support primary functions and that typically have a lesser social impact. They are quite numerous and the list below introduces some of the most significant ones.

Search function: this function aims to provide information search capability in order to provide users with relevant information. GSN should indeed offer information retrieval functions based on simple pull technics (e.g., search form) as well as on push technics (e.g., based on the user profile, browsing history and declared topics of interest). Advanced information pulling technics include delegating repetitive search tasks to an intelligent agent that systematically retrieve, filter, and present information to its user. In an push information search function, the user plays a less active role as information is "pushed" and provided as a list of recommendation or suggestion.

Membership function: this function aims to manage the process of a user joining a social network by opening an account or adding circles, contacts, connections, fans, followers, and so forth. This process typically features a registration form to be completed with a user's personal information. The way in which members complete their profiles (i.e., whether they fill them out partially or completely) offers a clue about their level of activity on the SM. Useful information to be derived from the membership function is not really found within the way users create their profiles, but within the quality of information in their profiles. Certain users intentionally disclose minimal information in order to remain anonymous and avoid mixing their private life with their public life. Different SM platforms feature various membership and profile systems depending on the nature of the relationship as emphasized by the network (e.g., friendly like Facebook, or professional like LinkedIn) in order to best protect users' identities. In a business context of social networking, this function could incorporate functions such as a smart address book, a card or a fan page. Such potentially business-friendly elements suggest that the membership function can be a gateway to devising a synergetic social tool.

Entertainment functions: these functions include gaming applications and "ecodgets". The term "ecodget" derives from both "ecology" and "gadget", referring to programs that operate like Windows' widgets. They are generally based on a single principle and serve just one function: the interpretation and display of continuous or discontinuous data streams (e.g., RSS). These ecodgets provide live streams of information to users. In an industrial ecology context, they can be developed to offer specific and relevant functionalities, such as a feed providing the latest eco-industrial news.

Advertising functions: these functions offer advertisements on social media sites in order to attract companies to a social network. Such sites tend to offer advertising opportunities in order to generate revenues for the social platform. Ads are generally managed by advertising networks in order to garner the maximum possible amount of “clicks” for the advertiser. The actual management process of allocating ads to specific web pages and users is a complex process, outside the scope of this paper.

Link function: this function aims to integrate social media websites with other sites or blogs, through the use of hypertext links between a SM platform and an external web page. For instance, *Facebook* implements this function through its "Like" function.

There are also many other secondary functions specific to each individual SM platform. Such functions have been customized over time in order to adapt to the specific profile and demography of the community they serve. In other words, each social medium is characterized by a key concept. For example, *So.cl* is known primarily as a research system, *Twitter's* 140-character limit makes it suited to small-scale personal or professional communication, *Google+* has "circles" and *ResearchGate* is dedicated to academics, to name a few.

6.1.3 Analysis

A social network based on the aforementioned primary and secondary functions overall aims to provide a variety of services to promote the development of communities with either general or specific interests. For a community with very specific interests, such as the economic development within an industrial cluster or region through means of by-products reuse and mutualisation, these functions would need to be designed in order to accommodate the development of industrial symbiosis both through self-organized and planned modes. Such functions must therefore also acknowledge and cater to the diversity of users (e.g., industries in varying sectors, agents of economic development, municipalities, administrative regions, elected officials) and any need for information confidentiality. Both forms of industrial symbiosis development undoubtedly require some level of information sharing. However, in practice, this sharing is done only in a context where implicit trust exists between potential partners, or with a trusted third-party. Consequently, the promotion of industrial symbiosis through a SM platform requires the design of specific sharing and exchange functions that support the building of trust between organizations, in order to encourage the development of a membership base, which in turn increases the chance of industrial synergy being created or other forms of resource sharing.

Considering this need for trust, the potential role of such SM functions seems to be limited, at least in early stages, to the initiation of contact (i.e., the process of social networking) between potential partners and stakeholders, although advanced matching functions based on material, process and logistic compatibility still need to be developed. Along this line, other specific functions yet to be developed might also contribute to later phases of the development of such partnerships, as current social media functions appear to be too generic to allow for a degree of privacy which would please organizations using such a social media network for the purposes of developing industrial symbiosis.

6.2. A green social networking framework for the initiation of industrial synergy

Based on these definitions of primary and secondary social media functions, a social network has the following characteristics: it is interactive, web-based with social functions, and it has an actively growing database (i.e., as opposed to a passive one). Consequently, a green social media would have similar characteristics while also being designed to serve environmental objectives. Thus, Green Social Networking (GSN) as defined in this paper is an interactive web-based platform enhanced by social functions. It is based on an active database and aims to contribute to the development of industrial symbiosis and other resource sharing partnerships, in order to reduce the collective environmental impact of an industrial community. Figure 1 proposes a framework that identifies specific contributions that a GSN could make with respect to the initiation phase of an industrial synergy project.

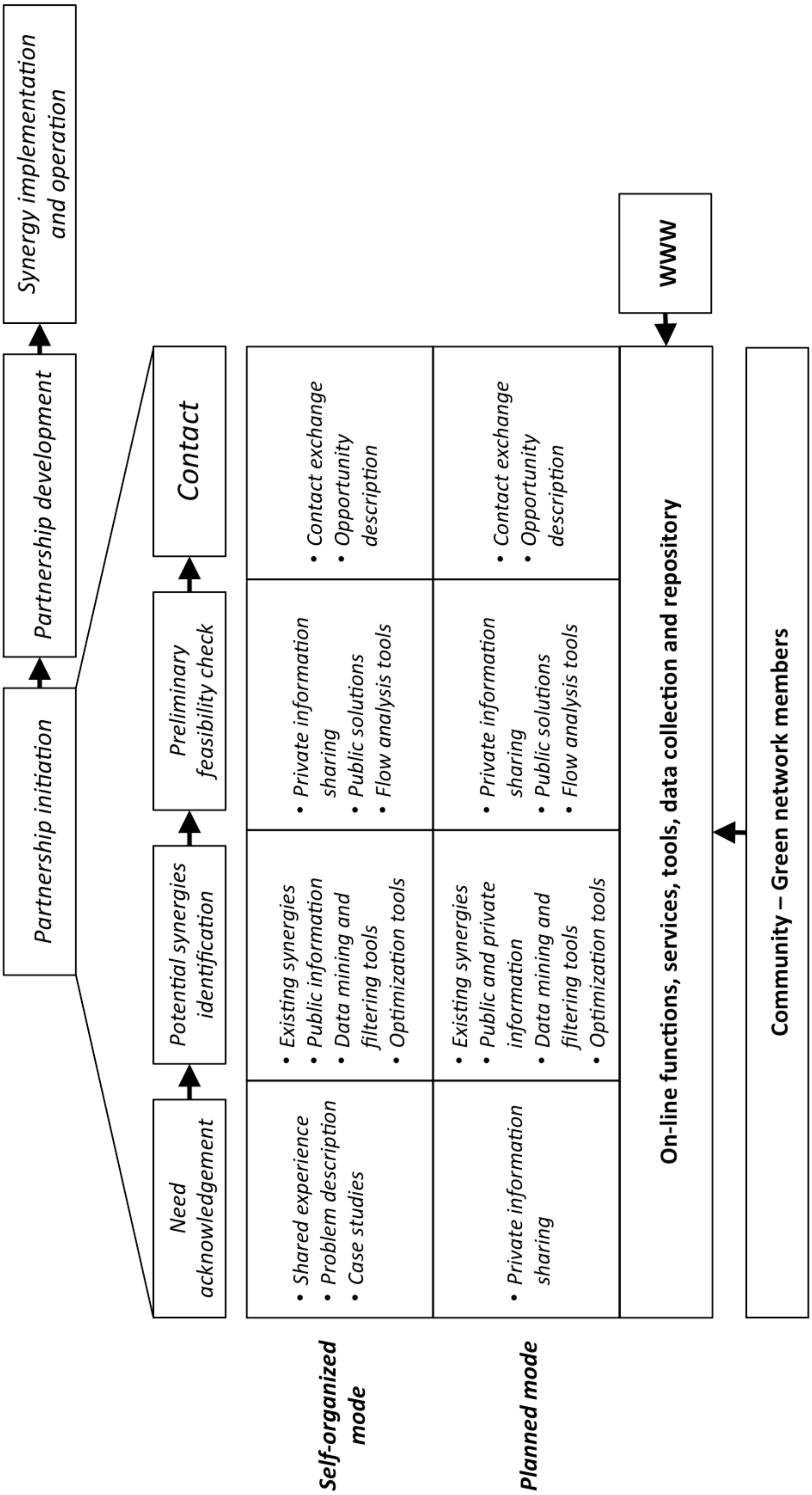

Figure 1: The contributions that social media functions could make to partnership development

In Figure 1, the development of an industrial synergy is divided into three general phases: (1) the initiation of a partnership; (2) the development of a partnership; and (3) the implementation and operation of a synergy. Phases 2 and 3 are outside the scope of this paper and as such, they will not be discussed. As previously mentioned, Phase 1 is further divided into four sub-phases: (1) an acknowledgment of need by an organization; (2) the identification of potential synergy between more than one organization; (3) a preliminary feasibility check for any partnership; (4) contact between more than one organization. During these sub-phases a GSN can contribute in different ways, according to whether the synergy is to be developed in a planned or a self-organized manner.

For instance, in the case of a self-organized initiation of an industrial synergy, the need acknowledgment could be triggered through users sharing their experiences or through the posting of public case studies, which would allow users to find information related to their problems or opportunities. Concerning the identification of potential synergies, a GSN platform can use private information contained in an organization's profile, disclosing that information, to analyze the compatibility between organizations (that is, some form of automated flow analysis). Tools based on data-mining or web-mining techniques can be used to automatically sort and analyze large amounts of data to find these compatibilities. If such compatibilities are found based on this information, the concerned organizations can be contacted privately through the GSN platform during a preliminary feasibility check phase, in order to further analyse any potential synergy. In other words, without really planning synergies as a third-party might do, the GSN can play the role of a catalyst or middleman between organizations, even before their first contact. If feasible synergy opportunities are found, the contact phase can be automatically initiated by the GSN platform by sending a formal multi-party invitation to connect, and a description of the synergy opportunity.

In the case of a planned synergy, the use of a GSN platform would be characterized by the proactive role taken by a third-party user (e.g., trusted consultants, agents of economic development). For instance, a need acknowledgment could be supported by the sharing of sensitive information contained in an organization's profile, which may eventually lead the third-party user to identify a by-product flow that could potentially be dealt with through an industrial synergy. During this phase, the experience of the third-party as shared on the GSN can directly contribute to the identification of further similarities between existing synergies and subsequently, opportunities. Concerning the latter three phases of synergetic development (i.e., identification of a potential synergy, preliminary feasibility check and initiation of contact), the process can be similar to that of the self-organized mode. However, the third-party user can take a more proactive role instead of letting the GSN platform automatically carry out flow analyses to identify synergies.

A GSN platform can also feature embedded optimization tools, as proposed in Maillé and Frayret (2013) and Cimren *et al*., (2011), which serve to find optimal or near-optimal synergy configurations within a network of organizations. Such tools can be used in order to compute the level of compatibility between organizations, or recommend potential types of industries with high synergistic compatibility amidst a cluster or an eco-park.

6.3. Green social networking position framework

In order to better position the concept of GSN with respect to other IS applications, Table 4 proposes a classification of various enterprise and professional IS applications. On the one hand, Prestéo and SYNERGIe are IS applications that are specifically designed to support the identification of industrial synergy opportunities. They use various levels of information and are mostly single user-oriented, hence they do not support any social functions. On the contrary, the BRIQ (the Québec Industrial Waste Exchange platform) is a proprietary IS application used directly by industrial organizations to connect market offers and demands for industrial by-products. However, unlike Prestéo and SYNERGIe, it uses a passive approach and does not analyze potential synergies in a proactive manner.

Table 4: Classification of generic and specific IS applications

	Non-social media	Social media
Non-green	• CRM (Customer relationship management) • ERP (Enterprise Resource Planning) • …	• LinkedIn • Viadeo • Tumblr • Instagram • Pinterest • Google + • Twitter • …
Green	• Prestéo • SYNEGIe • BRIQ • Second Cycle	• Green Social Networking

On the other hand, Viadeo and LinkedIn are general SM applications that support the building of professional networks. They aimed at managing personal careers and building users' professional images. However, other general-purpose SM applications, which are not intended for professional users, nonetheless utilize functions that could be useful for the initiation of industrial synergy. For instance, Tumblr is a place for informational exchanges between bloggers, which allows them to quickly visit a wide range of multi-media selections aggregated from a user's favourite blogs. Similarly, Pinterest is useful for sharing ideas and inspiration via "pins" and boards arranged around different topics. Also, Instagram serves as a simple forum for posting images while simultaneously providing opportunities for others to leave comments.

7. Conclusion

Business relationships, including industrial synergies, are often initiated on a casual basis, depending on the social relations between the leaders or decision makers of a business team. They are also sometimes facilitated by third-party organizations or individuals, who can directly connect people within business or industrial communities. In the specific context of industrial synergy partnerships, the connection process is sometimes supported by a third-party information system, whose main functions are to store data collected by experts, and to subsequently analyse these data in order to identify synergy opportunities based on the compatibility of flows between organizations (such as the supply and demand of a certain by-product on the parts of individual organizations).

Literature on industrial synergy shows that the intervention of a proactive third-party acting as a catalyst is an efficient way to identify and develop synergy opportunities. Similarly, social media forums have demonstrated their abilities to connect people and organizations based upon similarities or complementarities between multiple parties. They have also demonstrated an ability to effectively and efficiently disseminate information across vast networks. Therefore, the development of green social networks with the specific purpose of connecting organizations based upon the complementarity of their input-output flows is the logical next step for developing green IS.

In order to contribute to the development of GSN, this paper has highlighted the potential contributions of elements of existing social networks, with an analysis of existing social media functions through the lens of the basic steps of partnership initiation in a business sense. This analysis has demonstrated the limits of current applications for green social media, which primarily takes the form of general-purpose SM with a green orientation. It also revealed the usefulness of specific applications and information systems to automatically analyze the material flow compatibility between organizations, and to optimize the configuration of industrial synergies.

This proposed framework aims to guide the development of next-generation GSN platforms, which are yet to be developed. As such, future work on this subject would include the development of such a GSN platform as well as the testing and validation of its functions to contribute to promoting the development of industrial synergies.

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