11th International Conference on Customization and Personalization MCP 2024
The Power of Customization and Personalization in the Digital Age
September 25-26, 2024, Novi Sad, Serbia

EXPLORING THE POTENTIAL OF ONLINE SALES CONFIGURATORS AS TOOLS TO ASSIST INDUSTRIAL SYMBIOSIS NETWORK

Chiara Grosso[1][ORCID 0009-0008-2691-3947], Chiara Iannaccone[1], Luca Fraccascia[1,2][ORCID 0000-0002-6841-9823]
[1]Department of Computer, Control and Management Engineering "Antonio Ruberti",
University of Rome La Sapienza, Rome, Italy
[2]Department of High-Tech Business and Entrepreneurship,

Abstract. *Industrial symbiosis (IS) refers to a subfield of industrial ecology in which industries belonging to the same or different sectors adopt a collective approach to gain competitive advantage by exchanging materials, resources, and by-products. As a result, traditionally separate industries can engender an industrial symbiotic network (ISN), comprising at least three companies exchanging at least two types of waste, to gain economic advantage from interfirm exchange. To assist ISNs, specific online platforms have been designed as IS platforms. This paper addresses open questions in previous research on interfirm exchange between industries through an online IS platform. The aim is to assess whether and to what extent the implementation of a co-design tool, known in the literature as an online sales configurator (OSC), can assist processes of waste management to facilitate intra- and inter-firms in dynamics of industrial symbiosis. At the empirical level, this study considers two cases of Italian companies adopting IS and 15 IS platforms from different European countries. The empirical investigation detects the extent to which the implementation of an OSC can assist companies in their intra-firm and interfirm transactions on IS platforms. On the managerial implications of this study, it proposes the implementation of an OSC as a tool to support companies in value creation and acquisition in approaching IS. At IS networking level the study proposes the implementation of an OSC as a tool to overcome IS barriers with attention to knowledge sharing and companies' engagement within IS platforms.*

Keywords: industrial symbiosis, network, waste management, product configurator, waste design, sustainable value chain, circular economy

1. INTRODUCTION

Since 1989, when Frosch and Gallopoulos envisioned "industrial ecosystems," the potential of industrial symbiosis (IS) to foster green transition, innovation and resource usage, production efficiency, and waste valorization has been widely recognized in the literature(Chertow, 2000; Neves, Godina, Azevedo, & Matias, 2020). IS refers to a subfield of industrial ecology in which industries belonging to the same or different sectors adopt a collective approach to gain competitive advantages by exchanging materials, resources, and by-products(Chertow, 2000; Jacobsen, 2006). As a result, traditionally separate industries can engender an industrial symbiotic network (ISN), comprising at least three companies exchanging at least two types of waste, to gain economic advantages from interfirm exchange (Madsen, Boisen, Nielsen, & Tackmann, 2015). The synergetic exchange within an ISN extends the traditional journey of supply chains from linear to circular since the usage of wastes generated by one industry can be exploited by others to replace production inputs or generate new products (Fraccascia & Yazan, 2018; Patala, Salmi, & Bocken, 2020).

The European Commission currently recommends Industrial symbiosis as a strategic opportunity to achieve sustainable development goal (SDG) and apply the circular economy (CE) principles stated in Agenda 2050. A CE pays particular attention to waste design. Specifically, waste design enables the design of products whose characteristics and components allow them to be easily recovered, building them in an innovative and modular way (MacArthur, 2013).

An Industrials Symbiotic Network is strongly interrelated with an IS platform since both can assume a web-based nature. The promising role of an IS platform to provide companies with an environment favorable for matching their requirement in terms of waste management have been widely investigated (Fraccascia, 2020; Velenturf & Jensen, 2016; Yeo et al., 2019).

However how platforms can be programmed to foster beneficial relations between the actors IS ecosystems is still less investigated. The present study aims at combining waste design in the specific domain of IS with a co-design tool, known in the literature on mass customization (but not limited to) as an online sales configurator (OSCs) (hereafter named: product configurator or for shortness configurator).

Online sales configurators (OSCs) are knowledge management software programmed to support product design, development, and delivery (Felfernig, Hotz, Bagley, & Tiihonen, 2014; Forza & Salvador, 2003; Salvador, De Holan, & Piller, 2009). Especially in mass customization domain, OSCs play a key role as tools that provide customers with highly engaging shopping

experiences (Grosso, Forza, & Trentin, 2017; Sandrin, Trentin, Grosso, & Forza, 2017; Trentin, Perin, & Forza, 2014)

The purpose of the present study is to assess whether and to what extent the implementation of an online sales configurator (OSC), can assist processes of waste management to facilitate intra- and inter-firms in dynamics of industrial symbiosis. Specifically, to assess configurators' potential (if any) to provide companies with a tool for "waste configuration" that can (or cannot) facilitate IS dynamics of value creation and acquisition and networking. At IS networking level the study proposes the implementation of an OSC as a tool to overcome IS barriers with attention to knowledge sharing and companies' engagement within IS platforms.

With the aim of providing an initial framework grounded on real cases, the present research analyzed findings from two case studies of Italian companies implementing IS (but not engaging in IS platforms) and 15 active IS platforms from different European countries. This empirical investigation provides a preliminary overview on the extent to which product configurators could assist IS dynamics at different levels (e.g., value creation and acquisition, waste design, as well as why IS platform would benefit from its implementation (e.g. in information sharing, companies' matching).

Regarding the theoretical implications of this study, it proposes a framework to facilitate the establishment of a virtual market for secondary materials, by-products, and waste. Regarding the managerial implications of this study it proposes the implementation of an OSC as a tool to support companies in exploiting the benefits of IS dynamics. To delve into processes that could facilitate companies in exploiting the benefits of IS is crucial to assure companies with high levels of value creation and value acquisition.

This study presents the early stage of an ongoing research project on sustainability and circularity models. The remainder of this paper is structured as follows. Section 2 depicts the theoretical background of industrial symbiosis. Section 3 describes the research design and the methodology. The findings are reported in section 4 and discussed in section 5. in terms of contributions to related works and in section 6 in terms of contribution to research on the potential of online sales configurators as tool to assist IS network. Conclusions and further research are described in section 7.

2. THEORETICAL BACKGROUND

2.1 Industrial Symbiosis

The paradigm shift from linear model of production and consumption to circular models of production and consumption aim at providing tools to create value with processes decoupled from the consumption of primary resources but includes resources derived from waste materials (Blomsma et al., 2019). To this end, "waste design" which refers to design product having in mind it's easy dismantling plays a key role. Specifically, waste design enables the design of products whose characteristics and components allow them to be easily recovered, building them in an innovative and modular way(MacArthur, 2013). Despite its crucial role, waste design is not yet widely applied due to the numerous inefficiency factors that still characterize it, such as the generation of waste that is not easily preventable in different phases of the production process. Especially, a model of waste management that are widely evolving is the cooperation between companies to create economic value from waste namely, Industrial Symbiosis (IS). IS is not new form of cooperation but its cooperative model is recommended by European Commission as a strategic opportunity to achieve sustainable development and circular economy model. The idea of industrial symbiosis was developed by two geographers between the 1930s and 1940s. The two defined it as "*the structuring of two or more industries settled in an area*" (Desrochers & Leppälä, 2010). Industrial Symbiosis can be defined as a collaborative approach that involves the interaction between different industrial plants, which in reality are separated into dissimilar industries, through the physical exchange of materials, energy, water and services generated as waste by a company, the which are used as inputs by another company, and which would otherwise go to landfill, but also sharing of related infrastructure services (Chertow, 2000; Fraccascia, Magno, & Albino, 2016; Jacobsen, 2006). According to Richardson (Richardson, 2005), an optimal implementation of the industrial symbiosis model includes a reduction of waste going to landfill, by an exchange of such waste between companies. To this end, a company that produces waste can implement two different strategies: at intra and inter films levels.

Internal exchange, which involves using this waste within the company. As for the external exchange there are two possible strategies to manage Industrial Symbiosis:

(i) Internal exchange + input substitution;

(ii) Internal exchange +generation of new products.

External exchange which involves sending them to other companies. As for the external exchange there are three possible strategies to manage Industrial Symbiosis:

a. External exchange + input substitution,

b. External exchange + generation of co-products,

c. External exchange + generation of new products.

In these three cases, companies can share the costs of the industrial symbiosis and therefore a similar scenario can also be supported by small companies; furthermore, the benefits are related to more than one company, and not just one as in the previous cases, and cooperation can also take place between very different companies if the conditions exist(von Kolpinski, Yazan, & Fraccascia, 2023) (van Capelleveen, Amrit, & Yazan, 2018). Additional to cost sharing and reduction the benefits connected to industrial symbiosis are multiple and can be categorized into economic, environmental and social benefits (Chertow, 2000; Jacobsen, 2006). However, the adoption of IS processes for waste management is not without challenges and obstacles that made IS a model approached with distrust from companies that do not know it yet.

2.2 Industrial Symbiosis Platforms

Industrial ecosystems are strongly interrelated with platforms, defined by Iansiti and Levien (Iansiti & Levien, 2004) as "asset in the form of services, tools, or

technologies that offer solutions to others in the ecosystem". In industrial ecosystems, the actors are resource providers and resource consumers. In platform ecosystems both, resource providers and suppliers, are demand side users, because they consume services that help them to create an information system to manage their resource flows. The promising role of platform for Industrial Symbiosis has been recognized in literature also at interdisciplinary level (Albino, Fraccascia, & Giannoccaro, 2016; Fraccascia, 2020; Fraccascia & Yazan, 2018; Velenturf & Jensen, 2016) Whether implemented accordingly with IS principles a platform for Industrial Symbiosis Network can deliver the following benefits to its users:

- Facilitate knowledge information sharing and allow access to underused resources, encouraging the correspondence between supply and demand in the waste market;
- Give users the possibility to choose between a wider range of waste; (waste variety management)
- To offer the same waste to wide range of possible partners, so as to choose one or more relationships that ensure the best economic profitability to the offering company
- Time and costs saving when searching for a partner,
- To weave relationships that go beyond territorial constraints, through appropriate assessments of logistic costs to consider a wider geographical context
- To promote the purchase of materials at lower costs and allow savings on waste disposal costs;(considering that IS imply other type of costs e.g. waste transportation)
- Establish a database to collect useful information at the government level, to find key variables to allow the replicability of best cases, as well to address any obstacle to work on possible alternative solutions.

Despite the benefits of a platform for the IS network, the development of online platforms is not merely related to the adoption of the IS practices but also to ensure its effectiveness. To this end, it is essential that a large number of companies get engaged in IS networks so as to provide as much information as possible, but also those information that are relevant to motivate other companies in being engaged. The engagement of a large number of companies in IS networks requires overcoming the several limits that current IS platforms still have.

- First of all, to be programmed to be easily accessible so as to fulfill, the lack of awareness by companies on principles and benefits of industrial symbiosis;
- The lack of available information and knowledge. Current IS platforms are not provided with enough data and information to be used effectively.
- Companies' unwillingness to and/or difficulty in sharing information and knowledge; Distrust because of confidentiality issues, manual effort required for data entry, access restrictions not accessible for new participants, not operational or not used. Non-transparent, inefficient exchange of information and knowledge;
- Lack of information-sharing mechanisms and infrastructure. Generally, these tools are online repositories that provide myriad ways to disseminate and share information and knowledge as well as facilitate the so-called "matching". However to foster beneficial relations between the actors of an IS ecosystems requires to focus not only on information sharing but also on provision of related services

Despite industrial symbiosis and waste design being deeply correlated, research is predominantly concerned with providing information and knowledge.

3 METHOD

3.1 Research design

This study presents the early stage of an ongoing research project on sustainability and circularity models. Within the scope of the research project, this study focuses on tools that can foster sustainable and circular dynamics. In detecting potential tools, the study is focusing on product configurator as tools to assist IS intra and intercompany dynamics and Networking dynamics via web-based platform. To explore the potential of implementing product configurators, both perspectives are considered at the intracompany and the intercompany levels. At the intra company level, the research team collected data by interviewing representatives of Italian companies that already implement IS processes. At the intercompany level, the study identifies ISN platforms included in related works. The findings are discussed by providing the rationale behind the specificities of a configurator and its potential (if any) as a tool to assist IS dynamics and networking.

3.2 Case study

The two cases were selected from a sample of Italian companies included in a report on best practices in a CE[1]. Given the low rate of responses to a preliminary search, the search for a sample was broadened by browsing the web with the following criteria:

a) *"company" + "several industry sectors were included" + —circular economy*
b) *"company + several Italian regions were included + —circular economy"*
c) *merging a and b: "company" + "industry sectors + Italian regions + —circular economy"*

As a result, a sample of 10 companies was identified, and their representatives were interviewed on IS-related issues. In the sample, it was found that only two companies were implementing IS, and they then became candidates to be included within the scope of this study.

To analyze the characteristics of IS platforms, this study refers to the results of a related study, that is, the SYMBi[2] Interreg project in which the involved partners evaluated the active platforms of an ISN.

[1] 100storie_def_web_pag_singole_25-05-18_1527247969.pdf (europa.eu)

[2] for more details on the project named INDUSTRIAL SYMBIOSIS FOR A RESOURCE EFFICIENTECONOMY: https://projects20142020.interregeurope.eu/symbi/

4 FINDINGS

The findings on the case studies are reported here with a case narrative approach (Åhlström & Karlsson, 2023). To the purpose of the present study is reposted a narration of the interviewees' when describing their companies and the barriers encountered by the latter in implementing IS.

The finding of related work serves to support the rationale behind the proposal of OSC implementation as a tool to exploit IS network transactions on web-based platforms. As well to provide an empirical basis on what items to consider in the analysis of a wider sample of IS platforms planned for the development of the present study. In particular to detect which factor.

4.1 Case studies

Company A

Region: Veneto
Country: Italy
Interviewee: the CEO & Founder
Year of foundation: 1900
N of employees: 9 internal and several in outsourcing.
Waste management of different materials, specialized in waste of graphite

Narration of the interview.

As the CEO stated the company practices "positive symbiosis" which refers to sharing materials, but also know-how and production processes with other companies. The sharing involves companies from different industry sectors. The aim of the IS adopted by the company is to carry out a win-win growth process that fosters a positive impact on the territory and the community. How it works. Other companies come to us with their waste materials and resell the waste in the form of a new product. To do so, I try to think if I can make something beautiful with that specific waste. To this aim, it is crucial to merge skills and expertise from both companies' sides, the experiences we have and those that has the company that is bringing the waste to be reinvented.

We deal with the companies themselves, with their experts who give us regulatory information, which is constantly changing, rather than technical, so that we can look for a new type of processing to transform those products, and we can have intuition about what to create. We spend a lot of time in their laboratories. My job is to take their skills and bring them to a new sector, who knows the characteristics of that material better than them? I always say that our customers are also our research and development department.

To summarize, initially, therefore, we took the waste from the companies, and once we transformed it into something else we resold it to the same companies. We sell a new version of the initial waste material. We didn't accept waste without the certainty that after their transformation they would buy them back, because we don't want to create warehouses full of stuff lying there.

To make an example, Gibus, which produces awnings, asked us to transform the excess fabric from manufacturing, which would have become waste, and we made it into office gadgets, such as notepad holders. We did the same thing with Pirelli tyres, Nestlè plastic and graphite powder. In particular on this specific waste remanufacturing we got a level of expertise on graphite remanufacturing (e.g. in construction, to dye clothes, pencils) that made us able to train others in implementing graphite remanufacturing processes. Thanks to the level of expertise we achieved, Perpetua has borne a spinoff of company A, dedicated to the treatment of waste from graphite. We have patented processes that allow us to use graphite powder waste to make pencils, which are totally recyclable, and with the same methodology and the same graphite we also create molds and dyes for bags and t-shirts. AS we progressed in waste management we learned how to implement similar waste management processes for different waste materials.

To conclude, our positive symbiosis includes looking for alternative solutions in waste remanufacturing with a service customized on the specificities of each customers (i.e. companies that sell us their waste); and also we have started to spread our innovative manufacturing processes, and we are teaching how to use graphite powder in several industry sector apparently far from the using graphite before.

Barriers encountered by Company A in implementing IS

Convince companies to take part in the symbiosis, make them understand that it is a common project, learn to give something in return in terms of knowledge and competence, and have a "win to win" approach. If we are afraid of sharing information or that someone else will copy us we don't move forward.

Easy comparison with similar remanufactures products

Company B

Region: Veneto
Country: Italy
Interviewee: Marketing Manager Graphic Specialities
Year of foundation: 1700
N of employees: 250
Waste management of agro-industrial waste materials

Narration of the interview.

Company B is a company specialized in the production and creation of creative molds and technical molds, used mainly in the production processes of various sectors, such as fashion, design and clothing. We also have a whole series of paper products that we have been selling for over 40 years to schools, offices and so on and the characteristic of some of these products of ours is that to make them we do not use virgin cellulose, but use alternative materials. Basically agro-industrial waste materials, such as orange peel, as well as other plant waste, and even algae. About the use of algae, the goal was to reduce the proliferation of algae in the Venice lagoon. Given the variety of waste materials we have partnerships with various stakeholders in the industrial supply chain and there is no limit to the companies we can involve, because new solutions can always be found to valorize other companies' waste and use them in our production processes.

Barriers encountered by Company B in implementing IS

At consumers' level a barrier is the customers' perception of products obtained using secondary raw materials since it was perceived as lower quality products, because they often have different characteristics, for example the paper has a different color, it is a significant obstacle. To date we have surpassed it but the first ecological paper introduced by us on the market clashed with people's distrust. At company levels in my opinion the main barrier is due to the lack of information, many companies do not know the potential of their waste, they are not aware of how it could

be valorized and do not know how to contact other industrial entities that may be interested in their waste or by-products. This is no longer our case because we are known and therefore companies come to us, but I am sure an obstacle is precisely this lack of a network between companies, which can compare and understand how the waste of one becomes input for another.

5 RELATED WORKS

Based on finding from the on Digital tools & pathways for Industrial Symbiosis Platforms, conducted by the Government Office for Development and European Cohesion Policy of Slovenia (SVRK), 15 cases of online tools for Industrial Symbiosis Network. CYRKL platform, SYNERGie 4.0, Materiaalitori, Biomass Atlas, Clean Way, Symbiosis Platform, Circularity Assessment Scoring 2.0 (CAS 2.0), Oils & fats digital platform, SFRIDOO, Symbiex.es, Zero Waste Map, DIADYMA Reuse center, Green Star, E-SYMBIOZA, Syner platform.

Platforms were classified with a peer review was conducted by 9 project partners from 7 countries who fulfilled survey and classified the platforms in scale from 1 to 3 to identify the best practice in terms of: (a) functionality, (b) usability, (c) sustainability; (d) added-value, (e) transferability to other regions. The evaluation was made by subsisting a survey to evaluate the four above-mentioned dimensions, in a scale from 1 to 3 points. Based on results from the report the 15 platforms were evaluated as best practice and good practice based on the scores on the 5th dimensions

Table 1. IS Network platforms rated as best practice

Name of the Platform/	Country of implementation	Score, a, b, c, d, e criteria	Platform URL
SYNER platform	Spain	12.5	*https://synerplatform.com/*
CYRKL platform	Poland	13.9	*https://www.cyrkl.com/en*
SYNERGie 4.0	Slovenia	13.7	*https://international-synergies.com/what-we-do/software/*
Clean Way	Finland	12	*https://www.cleanway.com.au/*
Materiaalitori	Finland	13.2	*https://www.materiaalitori.fi/*
Biomass Atlas	Finland	12.4	*https://biomassaatlas.luke.fi/?lang=en*
CAS2.0	Slovenia	11.5	*https://synerplatform.com/*

To the scope of the present study platforms rates as best practice are considered, to subsequently include other set of platforms.

Functionality (a)

Results on functionality: refers to the range of functions that each tool serves, as well as the extent to which it fulfills its goal(s). Platforms with high score in functionality (i.e. Symbiosis Platform, Materiaalitori) were founded with highest ability to deploy at least 5 primary functions to support of IS dynamics, namely improvement of waste valorization,

- assistance in identifying potential synergies;
- management of industrial symbiotic schemes;
- facilitation of territorial industrial-waste management;
- facilitation of the virtual market for secondary materials operation.

In addition, the Symbiosis platform provides customized service to companies by developing individual reports on potential matches of interest; Materiaalitori actively promotes the national Waste Act.

SYNERGie 4.0 and CYRKL platform were found with a high degree of ability to deploy three primary functions (i.e. assistance in identifying potential synergies, management of industrial symbiosis schemes, and facilitation of a virtual market for secondary materials/by-products/waste).

Usability (b)

The usability criterion refers to the users' experience and, specifically, to the extent the latter find the tool simple and easy to use. Platforms with highest score in usability (i.e. Materiaalitori and Biomass Atlas) were found to be easy and simple in use, since any technical support and/or expertise was required while resources and instructions were publicly provided.

In particular, Materiaalitori provides easy access to the platform to all organisations in Finland.

SYNERGie 4.0 was found to be easy to use since it provides a translation feature to facilitate users' experience on a global scale. CAS 2.0 looks after its usability by providing activity of dissemination to raise companies' awareness on economic value derivable by transiting to a circular economic model.

Sustainability (c)

refers to the long-term outcome of the practice, namely the extent to which involved actors will continue benefiting from its use in the future, as well as the positive impact it might bring on the circular economy in the implementation area(s). Platforms that received highest scores (i.e. CYRKL Materiaalitori, Syner, and SYNERGie 4.0 were founded with great potential to continue its operation long-term. In particular, Materiaalitori ensures its viability both by offering easy access to all organisations at national level and by building cooperation by exchanging information with other platforms. The degree of sustainability of Syner relies on its orientation to be innovative and inclusive by promoting stakeholders' participation to guarantee a positive impact on the wide-area. SYNERGie 4.0 was found with high potential of growth per year pointing out its potential to operate long-term (statistical data shows that resources and organizations on the platform grow 10% per year).

Added value (d) refers to the final outcome of the practice in terms of the positive change it might have brought in the implementation area(s). Platforms with high rate of added value (i.e. Materiaalitori, Syner, SYNERGie 4.0, and CYRKL) based but not limited to the number of organizations joining the platforms when the evaluation was runned. In detail, Materiaalitori had 1547 users/organization registered. SYNERGie 4.0 hosted data of 34,000 organisations, promoting local sourcing and reuse opportunities for companies across 23 countries. CYRKL platform registered 12,000 clients, becoming the largest platform for the exchange of secondary raw materials in Europe. Finally, Syner counted with 52 companies.

Transferability (e) transferability: refers to the potential of the tool to be transferred in other regions/countries
Regarding the evaluation of transferability dimension, platforms that have been already transferred in other regions/countries have been assigned with 3 points. As a result, CAS 2.0, SYNERGie 4.0, and CYRKL platform have been rated with the highest score.

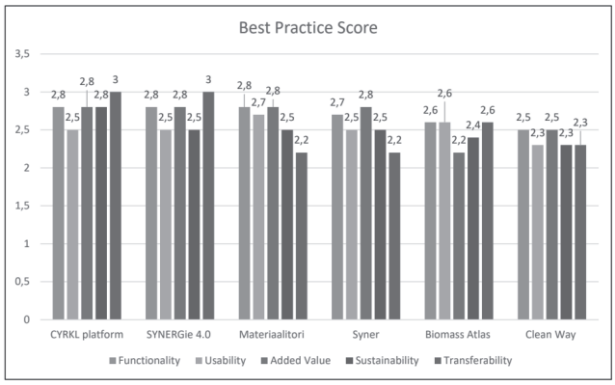

Figure.1 Overview of best practice IS Platforms
Source: SYMBi project

The first step of the present study includes an initial analysis of best practice platforms based on browsing into each platform. As preliminary consideration it appears that the majority proposes service of assistance and guidance to orientate companies, and services of matching within companies registered in the same platform.
In a first instance, a part SYNERGie 4.0 which is a software itself, platforms mainly act as mediators within actors involved in the potential symbiosis. CYRKL platform was considered vulnerable to fraudulent information, with low potential in trust building among users. Within the sample of best practice platforms do not provide a clear o publicly accessible to tools and/or features to simulate any match based the match between demand and offering. In the next step of the study is planned to interview referents from platforms to delve into what type (if any) of digital tool are implemented in the platform to enable process of input/output matching and/or processes of waste redesign.

6. DISCUSSION

6.1 Exploring the potential of a configurator as tool to support IS dynamics

This paper aims to provide a conceptual framework that merges IS dynamics with tools for product configuration, adopted as an interface for digital customization strategies to delve into possible services that will assist in IS network transactions on web-based IS platforms. The present conceptual framework merges two approaches—customization strategies and waste design in the IS domain, with particular attention to IS platforms.

Regarding the first approach, product configurators are tools that enable *customization strategies*. Product configurators' interfaces are implemented with knowledge management software, programmed to support product design, development, and delivery. The routine for a configured product includes (i) receiving individual customer requirements, (ii) configuring the product based on the defined solution space, (iii) performing the calculations and, finally, (iv) generating all the necessary outputs, including proposals, bills of materials/quantities, price calculation datasheets and even CAD/technical drawings. Configurators can deploy several abilities to guide users' journey and enhance their implementation with recommender systems to support product design, development, and delivery in business to customer (B2C) and business to business (B2B) markets.

Assuming that every company produces its specific waste and a single company can produce several types of waste, waste can be perceived as a customized material. As well, waste material can be customized to serve each product variant.

From the *waste design* perspective, with reference to the design for remanufacturing, the main goals are nondestructive dismantling and reassembly of a product via modular design and interchangeability (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Burke, Zhang, & Wang, 2023; Den Hollander, Bakker, & Hultink, 2017) Regarding the design for recycling, the ease of mechanical dismantling of similar components and materials, preferably in a single module, has been the focus to facilitate shredding, regenerating, and recycling (Hapuwatte & Jawahir, 2021; Morseletto, 2020). In this vein, product configurators could support companies in waste configuration strategies, given their key role in supporting the design of new product variants or modular organization, as well as assembly using the industrial chain's resources. The benefits of implementing a configurator include but are not limited to a shorter lead time, a low rate of errors, and the ability to meet customer requirements regarding product functionality, an optimized product design, and on-time delivery.

In the *IS dynamics* point of view, as a tool to enable the customization strategy, a product configurator can support IS dynamics at the intrafirm level, supporting companies in their remanufacturing design, also in terms of (re)configuration processes (Felfernig, Friedrich, & Jannach, 2001) Moreover, a configurator can support companies in their robust process design, in terms of reusing or recombining existing resources to fulfill differentiated companies' needs. Such requirements include the provision of possible combinations of ways to reuse the same resource (including waste) for components or manufacturing processes for different product variants (Salvador et al., 2009)

Internal IS strategies (intrafirm)

Given the capabilities (Sandrin et al., 2017; Trentin et al., 2014) and functionalities (Forza & Salvador, 2002a, 2008)of product configurators, their implementation for waste configuration purposes could support companies' internal exchange strategy with reference to internal exchange + co-product design.
To this end, a configurator as an interface for an enterprise resource plan (ERP) could support the customization strategy along the supply chain in the following ways:

a) mapping and identifying the waste attributes to be included in (or excluded from) a companies' "waste solution space" and

b) identifying their own solutions while minimizing complexity and the burden of choice in the "waste offering."

External IS strategies (inter-firm)

In the case of companies that already implement IS, configurators can support firms that adopt external exchange strategies, particularly those referring to external exchange + generation of co-products and external exchange + generation of new products.

The implementation of a configurator would add to remanufacturing processes an automatized supply chain that combines the handcrafted processes using product designers' creativity in redesigning waste into other products. A configurator could also support companies in matching customers' needs and specific requirements.

(Example of Company A)

6.2 Exploring the potential of a configurator as tool to support companies A and B in their IS dynamics

Company A: waste management of different materials, specialized in waste of graphite.

As stated in previous research, many small companies are forced to offer a wide variety of products and (often) to respond to the market with customized solutions (Forza & Salvador, 2002a, 2002b). Currently, this can be the case of companies in the waste management sector. Small enterprises could gain competitive advantage by implementing a product configurator. The competitive advantage can be derived from several improvements that a product configurator can bring to internal working practices and interfirm coordination by aligning working practices between the firms. Additionally, due to the capabilities that a configurator can deploy (Trentin et al., 2014), it can present to customers a configuration dialogue that drives them, as far as possible, toward the specification of product variants that tend to require a low content of customization features. In the case of Company A, customization features can require the redesign of the same waste material (e.g., graphite), but in different industry sectors, the customization features may not differ from a previous product redesign adopted for waste manufacturing, that is, the same design but with different materials or different materials for the same redesign. In this case, the operational efficiency will be enhanced considerably. The adoption of product configurators can offer to companies in the waste management sector a digital interface to make their offerings accessible, clearly communicate the added value of customized remanufacturing, and foster collaborative synergies with other firms in the same sector, which form the basis of ISNs

Company B. waste management of different plant based materials.

The implementation of a configurator to support a large firm such as Company B can serve as a tool for efficient management of the variety of product solutions that the company can propose to its customers. The capabilities that a configurator could deploy and the benefits related to both the product configuration process and its purchasing could help companies in overcoming customers' reticence in purchasing products made of raw materials. For example, companies could engage customers with a high level of creative and authorship benefits in co-design processes. Whether a configurator is implemented with the ability to drive customers toward sustainable configuration, they could be aware of a product's sustainable value that could positively increase their willingness to buy.

6.3 Exploring the potential of a configurator as tool to support IS platform

Merging configurators' functionalities with ISN dynamics could serve as a tool to support a platform in complying with functionality drivers (i.e., assistance in identifying potential synergies, management of IS schemes, facilitation of territorial industrial-waste management, facilitation of the virtual market for secondary materials' operation).

The implementation of a configurator could help in overcoming the detected barriers to knowledge sharing. For example, a configurator could provide a set of reliable information by providing a trustworthy price calculation datasheet.

As for the barriers concerning companies unwilling to engage in IS, the capabilities and functionalities deployed by configurators can deliver added value to such companies and motivate them to join an IS platform implemented with a product configurator instead of one without it. Thus, a configurator can serve as a facilitator of synergies between companies that seek collaboration on waste management but are unaware of how to implement IS dynamics, which form the basis of ISNs.

In terms of *IS platform usability*, a configurator can demonstrate possible configurations to advise companies on how waste can be converted into new product variants while providing information about the related benefits and costs of each variant. Long-term *IS platform sustainability and transferability* as tools for co-designing a product configurator could engender and/or enhance processes of open innovation. Therefore, its implementation could support the identification of synergies in accordance with fast-evolving markets for secondary materials, by-products, and waste via an IS platform.

Inspired by Cuc and Tripa'(2018) study on redesign and upcycling, an exemplification of possible waste design support provided by a product configurator is provided in figures below (fig.2-3). Hypothesizing a company (T) that sells trousers (Fig. 2), its waste material could be sold to a company that can exploit the excess textile. Otherwise, Company T has to dismantle such waste, with its implications in terms of additional effort and cost.

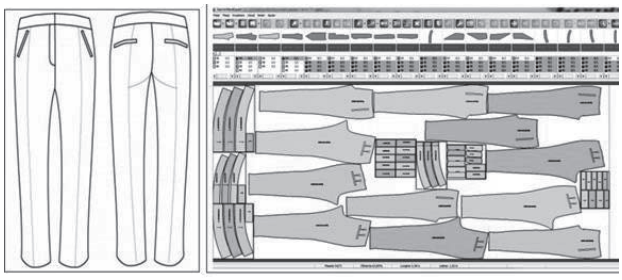

Figure.2 product and exceeding material from company (T) Source: our elaboration from Cuc and Tripa, S. (2018)

The product configurator implemented with proper capabilities and the functionality to support IS dynamics could assist in the matching process between the waste material and the products manufactured by another company within the ISN. An example with a product from Company S that produces shirts.

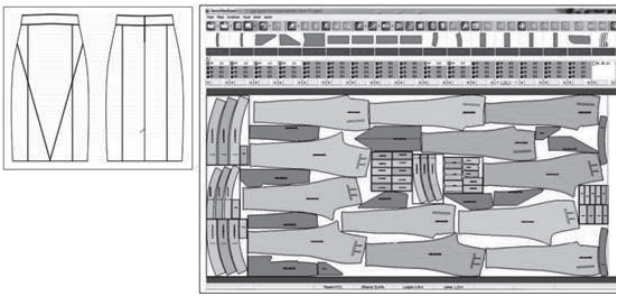

Figure.3 matching exceeding material of company (T) with product produced by company (S) Source: our elaboration from Cuc and Tripa, S. (2018)

7 CONCLUSIONS

The present study provides a conceptual framework that merges IS dynamics with tools for product configuration, adopted as an interface for digital customization strategies to delve into the configurators' potential to assist in ISN transactions at intrafirm and interfirm levels and on web-based IS platforms.

This study, which is part of an ongoing project focusing on sustainability and circularity management, empirically addresses two real cases of companies that have adopted IS dynamics. The two companies provided relevant information on their strategies. To analyze ISN platforms, related works on best practices are considered to detect potential configurator implementation. The discussion provides the rationale for the conceptual framework and its practical feasibility. Given the difficulties in identifying and interacting with the target companies (even extending the search to the national level), this study's findings contribute with a precious starting point for research in the same field.

At its early stage, this study provides an initial framework to link waste design in the IS domain (focusing on IS platforms) with a tool for customization strategies, namely a product configurator. The aim is to research the extent to which the configurator can act as a toolkit to facilitate the symbiosis process of waste management at both the collaborative intrafirm and interfirm levels. To delve into process that could facilitate companies in exploiting the benefits of IS is central to assure companies with high levels of value creation and value acquisition

The potentials to overcome IS barriers are discussed to provide managers with a basis to plan and/or rethink their waste management strategies by considering the benefits of the tool for waste configuration proposed in this study.

Further research is ongoing to address the limitations of the current initial stage of this study, that is, to extend the sample of platforms to newly detected IS platforms. At the technical level, the study will focus on the appropriate IT and ERP solutions to support waste configuration processes on Industrial Symbiosis web-based Networks.

Acknowledgments

This study was carried out within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from the European Union Next-Generation EU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3 – D.D. 1551.11-10-2022, PE00000004). This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them

8. REFERENCES

Åhlström, P., & Karlsson, C. (2023). 6 Longitudinal field studies. *Research Methods for Operations and Supply Chain Management*, 190.

Albino, V., Fraccascia, L., & Giannoccaro, I. (2016). Exploring the role of contracts to support the emergence of self-organized industrial symbiosis networks: an agent-based simulation study. *Journal of Cleaner Production, 112*, 4353-4366.

Blomsma, F., Pieroni, M., Kravchenko, M., Pigosso, D. C., Hildenbrand, J., Kristinsdottir, A. R., . . . Jönbrink, A.-K. (2019). Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation. *Journal of Cleaner Production, 241*, 118271.

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering, 33*(5), 308-320. doi: 10.1080/21681015.2016.1172124

Burke, H., Zhang, A., & Wang, J. X. (2023). Integrating product design and supply chain management for a circular economy. *Production Planning & Control, 34*(11), 1097-1113.

Chertow, M. R. (2000). Industrial symbiosis: literature and taxonomy. *Annual review of energy and the environment, 25*(1), 313-337.

Den Hollander, M. C., Bakker, C. A., & Hultink, E. J. (2017). Product design in a circular economy: Development of a typology of key concepts and terms. *Journal of Industrial Ecology, 21*(3), 517-525.

Desrochers, P., & Leppälä, S. (2010). Industrial symbiosis: old wine in recycled bottles? Some perspective from the history of economic and geographical thought. *International Regional Science Review, 33*(3), 338-361.

Felfernig, A., Friedrich, G., & Jannach, D. (2001). Conceptual modeling for configuration of mass-customizable products. *Artificial Intelligence in Engineering, 15*(2), 165-176.

Felfernig, A., Hotz, L., Bagley, C., & Tiihonen, J. (2014). *Knowledge-based configuration: From research to business cases* (E. Inc Ed.). Waltham, MA, USA: Morgan Kaufman.

Forza, C., & Salvador, F. (2002a). Managing for variety in the order acquisition and fulfilment process: The contribution of product configuration systems. *International Journal of Production Economics, 76*(1), 87-98.

Forza, C., & Salvador, F. (2002b). Product configuration and inter-firm co-ordination: an innovative solution from a small manufacturing enterprise. *Computers in Industry, 49*(1), 37-46.

Forza, C., & Salvador, F. (2003). *Configurazione di prodotto*: McGraw-Hill.

Forza, C., & Salvador, F. (2008). Application support to product variety management. *International Journal of Production Research, 46*(3), 817-836.

Fraccascia, L. (2020). Quantifying the direct network effect for online platforms supporting industrial symbiosis: an agent-based simulation study. *Ecological economics, 170*, 106587.

Fraccascia, L., Magno, M., & Albino, V. (2016). Business models for industrial symbiosis: a guide for firms. *Procedia Environmental Science, Engineering and Management, 3*(2), 83-93.

Fraccascia, L., & Yazan, D. M. (2018). The role of online information-sharing platforms on the performance of industrial symbiosis networks. *Resources, Conservation and Recycling, 136*, 473-485.

Grosso, C., Forza, C., & Trentin, A. (2017). Supporting the social dimension of shopping for personalized products through online sales configurators. *Journal of Intelligent Information Systems, 49*(1), 9-35.

Hapuwatte, B. M., & Jawahir, I. S. (2021). Closed-loop sustainable product design for circular economy. *Journal of Industrial Ecology, 25*(6), 1430-1446. doi: 10.1111/jiec.13154

Iansiti, M., & Levien, R. (2004). Keystones and dominators: Framing operating and technology strategy in a business ecosystem. *Harvard Business School, Boston, 3*, 1-82.

Jacobsen, N. B. (2006). Industrial symbiosis in Kalundborg, Denmark: a quantitative assessment of economic and environmental aspects. *Journal of Industrial Ecology, 10*(1-2), 239-255.

MacArthur, E. (2013). Towards the circular economy. *Journal of Industrial Ecology, 2*(1), 23-44.

Madsen, J. K., Boisen, N., Nielsen, L. U., & Tackmann, L. H. (2015). Industrial symbiosis exchanges: Developing a guideline to companies. *Waste and biomass valorization, 6*, 855-864.

Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling, 153*, 104553. doi: 10.1016/j.resconrec.2019.104553

Neves, A., Godina, R., Azevedo, S. G., & Matias, J. C. (2020). A comprehensive review of industrial symbiosis. *Journal of Cleaner Production, 247*, 119113.

Patala, S., Salmi, A., & Bocken, N. (2020). Intermediation dilemmas in facilitated industrial symbiosis. *Journal of Cleaner Production, 261*, 121093.

Richardson, J. E. (2005). The business model: an integrative framework for strategy execution. *Available at SSRN 932998*.

Salvador, F., De Holan, P. M., & Piller, F. (2009). Cracking the code of mass customization. *MIT Sloan Management Review, 50*(3), 71-78.

Sandrin, E., Trentin, A., Grosso, C., & Forza, C. (2017). Enhancing the consumer-perceived benefits of a mass-customized product through its online sales configurator: An empirical examination. *Industrial Management & Data Systems, 117*(6), 1295-1315.

Trentin, A., Perin, E., & Forza, C. (2014). Increasing the consumer-perceived benefits of a mass-customization experience through sales-configurator capabilities. *Computers in Industry, 65*(4), 693-705.

van Capelleveen, G., Amrit, C., & Yazan, D. M. (2018). A literature survey of information systems facilitating the identification of industrial symbiosis. *From science to society: New trends in environmental informatics*, 155-169.

Velenturf, A. P., & Jensen, P. D. (2016). Promoting industrial symbiosis: Using the concept of proximity to explore social network development. *Journal of Industrial Ecology, 20*(4), 700-709.

von Kolpinski, C., Yazan, D. M., & Fraccascia, L. (2023). The impact of internal company dynamics on sustainable circular business development: Insights from circular startups. *Business Strategy and the Environment, 32*(4), 1931-1950.

Yeo, Z., Masi, D., Low, J. S. C., Ng, Y. T., Tan, P. S., & Barnes, S. (2019). Tools for promoting industrial symbiosis: A systematic review. *Journal of Industrial Ecology, 23*(5), 1087-1108.

CORRESPONDENCE

Dr Chiara Grosso, Assistant Prof. University of Rome La Sapienza Department of Computer, Control and Management Engineering "Antonio Ruberti", Via Ariosto 25, 00185, Rome, Italy.
Corresponding: chiara.grosso@uniroma1.it

Ing. Chiara Iannaccone,
University of Rome La Sapienza Department of Computer, Control and Management Engineering "Antonio Ruberti", Via Ariosto 25, 00185, Rome, Italy,

Dr Luca Fraccascia, Senior Assistant Prof. University of Rome LaSapienza Department of Computer, Control and Management Engineering "Antonio Ruberti", Via Ariosto 25, 00185, Rome, Italy
University of Twente, Department of Industrial Engineering and Business Information Systems, Enschede, the Netherlands