A Multi-Level Approach to Improve Sustainability Performances of Industrial Agglomerations

Patrick Innocenti, Elias Montini, Silvia Menato, Marzio Sorlini

Abstract—Documented experiences of industrial symbiosis are always triggered and driven only by economic goals: environmental and (even rarely) social results are sometimes assessed and declared as effects of virtuous behaviours, but are merely casual and un-pursued side externalities. Even worse: all the symbiotic project candidates entailing economic loss for just one of the (also dozen) partners are simply stopped without considering the overall benefit for the whole partnership. The here-presented approach aims at providing methodologies and tools to effectively manage these situations and fostering the implementation of virtuous symbiotic investments in manufacturing aggregations for a more sustainable production.

Keywords—Business model, industrial symbiosis, industrial agglomerations, sustainability.

I. INTRODUCTION

INDUSTRIAL Symbiosis (IS) is a widely-discussed concept introduced decades ago to describe separate business entities engaging a collective approach involving the exchange of materials, energy, water, and by-products, in order to increase their mutual profit [1]. Thanks to the increasing request for sustainability-performing products and productions, in the latest years IS got a renewed interest as a potential promoter of investments simultaneously pursuing environmental and financial performances. Industrial agglomerations (i.e.: industrial parks, clusters, districts, networks) are a perfect context where collaboration opportunities are more likely to happen since companies are already used to interacting and existing physical infrastructures also allow to easily share inputs and outputs (and related information) [2]. Unfortunately, not all industrial agglomerations have the cooperation level required to reach a significant symbiotic behaviour useful for generating resource exchanges in terms of flows, information, knowledge, etc., and creating overall sustainability benefits. In the here-discussed research, an analysis of existing industrial agglomerations shows that none of them simultaneously pursue more than one element of the sustainability triple bottom line: decisions are always driven by economic and financial elements and benefits are quantified as a result of exchanged material flows

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[3]. This notwithstanding, several IS initiatives result in a reduction of the deriving environmental impacts of the industrial park/agglomeration. This (un-pursued) result is a side effect of the profit maximization, thus it is not optimized. Sustainability optimization could be achieved when social, environmental and economic aspects are simultaneously pondered at network level, though assuring the protection of financial interests of each economic entity participating to the cluster. The paper proposes a methodology that faces this challenge combining a (cluster-wise) centralized optimization engine considering all the three elements of sustainability, and a compensation mechanism aimed at financially rewarding companies asked to adopt behaviours resulting in a worsened financial performance. This is meant to force specific exchange flows where one or more companies could have economic losses but that entail an overall benefit for the cluster. An innovative business model supports the creation of a central institution that manages the interactions between the involved companies during the creation of new flows (communication, investments, solutions, etc.), and that is responsible of the management of expected gains originated by the new flows. Thanks to the proposed approach, several industrial parks can adopt the IS concept improving their sustainability profile though preserving each partner's financial and economic position.

Chapters II and III discuss the two concepts of IS and Sustainability, while their interaction is presented in Chapter IV, where major concerns and barriers to their simultaneous pursuit are highlighted. The innovative approach is presented in Chapter V. Conclusions and next steps are finally discussed in Chapter VI.

II. INDUSTRIAL SYMBIOSIS

The IS concept was introduced by Frosch and Gallopoulos [4] two decades ago, redefining the role of companies' secondary outputs changing them from wastes to raw materials for other processes. Wastes, such as heat energy, water and by-products, can be exchanged improving collaboration among independent companies. IS has been studied for several years by many researchers and, in 2000, Chertow et al. [1] developed a definition of the concept: "Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchanges of materials, energy, water, and/or by-products. The keys to IS are collaboration and the synergistic possibilities offered by geographic proximity." IS is designed on a natural eco-system metaphor related to biological symbiosis in which two different organisms mutually benefit

from a relationship. The translation in industrial contexts of the behaviour of such natural eco-system took various forms. In fact, IS was studied in industrial networks [5]-[7], eco-industrial parks [8], [9], and even in single business groups [6], [9], [10]. In the recent years, a more complete definition of IS has been provided by Lombardi and Laybourn [11] including concepts such as network, eco-innovation and mutually profitable transaction. Moreover, they dropped the constraint of (physical) proximity among the involved actors.

Relationships generated among companies thanks to IS initiatives allow to tackle three possible opportunities [12]: (i) by-products resource exchanges among two or more parties for use as substitutes for commercial products or raw materials; (ii) utility/infrastructure sharing and management of commonly used resources (e.g.: energy, water, wastewater, etc.); (iii) joint provision of services for common needs across companies such as fire suppression, transportation, road, and food provision. Industrial agglomerations are characterized by different type of collaborative behaviours, as shown in Table I [2], [13]. Moreover, depending of the level of collaboration inside the park, industrial agglomeration is a perfect context where IS is more likely to happen and companies are more encouraged to interact and easily share input and output among them. For example, industrial estate pursues IS concept only sharing infrastructures, on the contrary eco-industrial ecosystems share infrastructures, services and by-product resources.

TABLE I
INDUSTRIAL AGGLOMERATIONS SYNOPSIS

Type of industrial agglomeration	Collaborative behaviour
Industrial park	Facility sharing, cooperation, no resource exchanges, interest in new opportunities
Industrial cluster	Cooperation, no resource exchanges, no facilities sharing
Industrial estate	Infrastructure sharing, no cooperation, no resource exchanges
Industrial ecosystem	Cooperation, exchange of resource and by-products, facility sharing
Eco-industrial park	Cooperation, exchange of resource and by-products, facility sharing, interest in new opportunities
Eco-industrial network	Cooperation, exchange of resource and by-products, facility sharing, interest in new opportunities

As better described in Chapter IV, also in industrial parks/agglomerations IS initiatives are implemented as far as resulting in economic and financial benefits. Moreover, reasons for this focused vision also in industrial contexts where several infrastructural and functional elements would favour environmentally profitable exchanges are investigated.

III. SUSTAINABILITY

In 1987, the World Commission on Environment and Development defined sustainable development as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [14]. The attention to sustainability has been increasing sharply since the United Nations Conference on Environment and Development (UNCED) in Rio in 1992. One of the main outcomes was the definition of a program for sustainable development in all areas where human impacts the environment. Nowadays sustainability has become an important topic of daily discussions among policy makers, academics, industries and general public. Focusing on industry, a study performed by Deloitte [15] shows that 88% of respondents point at "efficiency and environmental technologies" as the most important opportunity to increase their competitiveness. Moreover, the same report shows that researcher and industrial managers suggest "better resource utilization" and "sustainability" as the most important strategic approaches for the future of manufacturing.

The sustainability definition has been refined by Elkington [16] introducing three different aspects (environmental integrity, social equity and economic prosperity) to guide sustainability research and practice and that need to be simultaneously pursued in order to be "sustainable".

In order to evaluate sustainability performances, specific methods and tools must be used. The most common and standardized ones are: (i) Life Cycle Assessment (LCA), (ii) Life Cycle Costing (LCC) and (iii) Social Life Cycle Assessment (SLCA).

The LCA is a tool for the evaluation of the environmental aspects of a product or service system considering all life cycle phases. Nowadays LCA is a consolidated tool thanks to dedicated standards: ISO14040 (Environmental management – Life Cycle Assessment – Principles and framework) [17] and ISO14044 (Environmental management – Life Cycle Assessment – Requirements and guidelines) [18] that allow to accomplish a unique and comparable environmental assessment. On the other side, LCC is a technique for the evaluation of the economic performance that products or services generate during their life cycle, considering one or more actors (suppliers, producers, users, distributors, etc.) and internal or external costs from extraction to the End of Life (EoL) phase [19]. LCC is useful for monitoring costs, making decisions and adding interests in products for costumers and financial sectors point of views. Unfortunately, LCC has not a dedicated standard for its development but it is possible to follow the same procedure provided into the 14040/44:2006 ISO for the Life Cycle Assessment, adapted to economic and financial elements.

Eventually, according to [20], SLCA is a social impact assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle encompassing extraction and processing of raw materials, manufacturing, distribution, use, re-use, maintenance, recycling, and final disposal. The social impacts are mainly related to human capital, human well-being, cultural heritage, socio-economy and social behaviour [21]. Similarly to LCC, the SLCA does not have an own standard framework, but following the UNEP/SETAC guidelines it is possible to adopt the ISO 14040.

In the recent years, a fourth approach emerged, named Life

Cycle Sustainability Assessment (LCSA), which provides an integration of the above-mentioned complementary three methods through [22], [23]:

$$LCSA = LCA + LCC + SLCA \qquad (1)$$

The main issue regarding the development of a common LCSA framework is the ability to effectively combine the three techniques, while respecting the different peculiarities of single assessment frameworks. An important contribution to the definition of an LCSA framework was carried out by the UNEP/SETAC association, that in [24] presents indications and recommendations on how to start a LCSA according to the LCA framework, but a combination of the impact/performances related the three areas of sustainability is still under investigations. In order to support LCSA practitioners facing the mentioned problem, institutions and researchers identified two possible approaches:

- Using decision analysis methodologies like the multi-criteria decision analysis (MCDA), multi-attribute value theory and the analytical hierarchy process (AHP). In recent years, these tools have been used by researchers to define an integrated sustainability index. For example, Traverso et al. [25] created a comprehensive dashboard that shows both separated and aggregated sustainability performances of a product/process. This has been later adopted also by the UNEP/SETAC initiative [26] showing how the three life cycle techniques can be combined [27]. Recently, Atilgan and Azapagic [28] proposed an integrated life cycle sustainability assessment, focused on the electricity sector, evaluating different scenarios using a unique sustainability score calculated weighting each sustainability aspect in accordance to the perceptions of the involved stakeholders.

- Converting each sustainability indicator in monetary values. Also in this case, few examples are available: Bent [29] delineated a first monetization of sustainability values in an alcohol producing company, stating that social and environmental impacts are composed by a monetary evaluation of externalities and shadow costs. Nguyen et al. [30] analysed different monetization processes of environmental impacts evaluating their consistency in a real case. Other studies have been performed by Weidema [31] and Velden et al. [32] proposing specific monetization solutions related to environmental and social aspects, respectively.

Nowadays, sustainability is considered a very important topic by government, companies and institutions, and, as deeply described in the next chapter, IS could be a driver concept for the introduction of sustainability in industrial agglomeration.

IV. SUSTAINABILITY AND IS

As reported in §II, IS initiatives are usually triggered pursuing economic benefits, while the improvement of environmental performances are (virtuous) side effects, obtained as a consequence of the primary economic goal. And that is true particularly for industrial agglomerations, where the potential for valuable IS could be amplified. Reasons for this resistance need to be investigated in order to find effective mitigation measures and approaches.

A first element to be considered is the way industrial relationships within parks arose. Paquin and Howard-Grenville [33] identified two different organizational approaches: "serendipitous" and "goal-directed". Serendipitous parks pursue IS only when potential gains are evident and firms can readily access each other to create value. In this case firms are motivated to join and develop particular networks looking only to individual goals. Goal-directed, instead, defined those industrial parks intentionally created by a coordinator in order to achieve collective or network-level goals.

Considering existing parks, a typical serendipitous approach was followed by the Kalundborg Symbiosis [9], [34]. In fact, in 1961 few enterprise managers developed a good collaboration between employees of the businesses involved starting to exchange minor resources in order to take advantages from the proximity of the companies and the economic benefits of this transaction. On this basis, other companies adhered to the Kalundborg Symbiosis achieving, as for today, 29 new flow exchanges involving 13 companies. Interestingly, also in this case, the park was born thanks to an agreement among companies based on potential economic benefits. Currently the park is also strongly focused on the reduction of environmental impacts but always considering positive economic benefits during the decision-making process. The Kwinana and Gladstone industrial parks [35], located in Australia, are other examples of serendipity since companies started to collaborate exchanging by-products, energy and other flows to pursue economic benefits. Also here the environmental impacts of their choices started to be assessed afterwards, mainly for monitoring purposes (and just marginally impacting non decision making).

Switching to the goal-directed approach, a huge amount of industrial cases can be mentioned, especially in China, because of the influence governments have on the economy, which is the most important driver for the creation of an industrial park. A notable example is the Tianjin Economic-Technological Development Area (TEDA) [36] founded in 1984 and including more than 4400 companies from different sectors (electronic and ICT industry, machine manufacturing, biopharmaceutical industry, and food industry). The park is managed by the Tianjin municipal government with the aim to create an advantageous economic zone for different companies, looking also at pursuing environmental benefits. Another example of "goal-directed" approach is well-represented by some German industrial parks, such as the Schkopau initiative. The park is governed by a single company, named "tenant", that is responsible of the recruitment of new companies, and of the conclusion of contracts between them when potential exchange opportunities arise. Also this park was created mainly to pursue economic/financial goals.

As examples show, the economic/financial purpose is always the guiding element in both serendipitous and goal-directed industrial parks. For serendipitous initiatives, it is the triggering element and usually remains the unique decision-making driver all along the park lifecycle. In goal-directed aggregations, sometimes the pursued goal is non-financial (at least the declared goal): promotion of local employment (in a given area), value-adding service provision for a shared environmental awareness, etc., but still just flows positively impacting on the economic profiles of each participant are activated.

Actually, also if not directly pursued, environmental benefits deriving from IS are often tangible. Sokka et al. [37], for example, analysed the environmental impacts of an industrial ecosystem around a paper mill using a life cycle assessment. From this analysis, they obtained that the IS results in improvements around 5% to 20% in most impact categories. A more recent study has been performed by Daddi et al. [38] that measured the environmental benefits of IS implemented in an industrial cluster of tanneries located in Tuscany (Italy). Also here, IS positively contributes to several environmental indicators such as climate change, terrestrial eutrophication and freshwater eutrophication. Still, no evidence is available in literature about impacts on social aspects.

In conclusion, the relationship between IS and sustainability can be summarized as shown in Fig. 1: IS initiatives and sustainability-enhancing projects belong to two different sets. Some projects belong to both sets (highlighted area), but this is not the result of a conscious choice: sustainability is not intentionally pursued but it is an indirect result deriving from IS initiatives that are activated starting from an economic-driven decision making. Improvements are thus necessary to increase the overlapping area between the two. In order to tackle this objective, in the next chapter a new approach is proposed to make sustainability a driving decision making element in IS contexts.
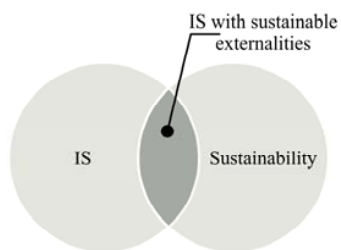

Fig. 1 Current relationship between IS and sustainability

V. PROMOTING SUSTAINABILITY-DRIVEN IS

An approach to promote sustainability in IS initiatives, with a peculiar focus on industrial parks, is here described. A new optimization equation needs to be created on which industrial agglomerations should base their decision-making process when a candidate IS initiative is activated. First of all, taking into account the definition of sustainability, it is clear that all its areas must be considered and somehow included in the decision-making process. Current choices are performed just focusing on economic aspects, while the revised version should include also the other two areas. The idea is to push industrial agglomerations to activate (at time t) the resource flows that allow maximizing the forecasted sustainability performances in a given time horizon (going from t to $t + t'$ where t' is a certain time period defined by stakeholders), calculated through the following objective function:

$$\max_{eco,env,soc} \alpha \sum_{i,k} env(i)_k + \beta \sum_{i,k} eco(i)_k + \gamma \sum_{i,k} soc(i)_k \ (2)$$

where α, β, and γ are the weights that stakeholders give to the specific sustainability areas depending on their strategy, i (going from 1 to n) are the involved companies) are the companies in the park participating to the new resource flow exchange, k is the time period going from t to $t+t'$, and eco, env and soc are indicators resulting from the weighted sum of single indicators belonging to a specific sustainability area. Moreover, particular situations could include that not all addends are simultaneously mandatory (e.g.: decision maker should transform one or more elements into a constraint of the optimization model). Actually, equations representing the currently used approaches (as described in Chapter IV) have A = C = 0 since environmental and social aspects are not considered. Moreover, in current decision-making processes, park decision makers usually don't have a unique equation to solve, but as many equations as the number of companies involved in the decision-making process. And the challenge is to maximize the value of all these equations. In particular, none of them can result in a negative value.

In sustainability-driven IS:

- all companies involved in the industrial agglomeration (more specifically, at least the ones involved in the exchange process) must be simultaneously considered;
- α, β, and γ must be all > 0;
- specific metrics have to be used to estimate both environmental (e.g. life cycle assessment), economic (Revenues – Costs, LCC), and social (SLCA) performances.

Unfortunately, the implementation of this approach is not free of troubles. Concerns derive from several aspects, whose related issues and possible solutions are explained separately below:

1. Organizational issue: Companies belonging to an industrial agglomeration are not prone to follow network's sustainability goals when one or more of the involved companies have null or low economic benefits from their participation. The problem is how to make these companies pursue inter-organizations benefits. Moreover, resources and by-products exchanges require that companies make available information concerning needed flows, own wastes, processes input-output, etc. that usually are hardly shared within different departments of the same company (intra-organization) and definitely not shared with other companies (inter-organizations);

2a. Economic issue: Companies must follow the market

dynamics of their sector and they must thus survive against competitors. The same reasoning can be applied to industrial parks, in fact also the park as a whole and in each of its nodes must preserve their competitive position. Competition is currently based only on economic/financial elements (including financial benefits deriving from the appropriation of positive environmental externalities). A constraint is thus needed limiting the possibility to carry out projects resulting in economic losses (also in extremely positive for the other sustainability aspects);

2b. Economic issue: In order to tackle the opportunity suggested by (2) and implement the proposed approach, new infrastructures could be necessary but it is necessary to identify who will pay for their construction/installation and maintenance.

3. Sustainability issue: The calculation of the sustainability performances, towards LCSA, considering (2), requires that environmental, economic and social impacts are "summed" while they are characterized with different measure units. In order to perform a right calculation, solutions to integrate the impacts of all three areas must be identified: for example, some authors suggest to use money as a common (external) impact measure, but some aspects cannot be translated into money. A solution needs to be sought.

1. Organizational-Related Solution

In §IV two different organizational approaches have been introduced: "serendipitous" and "goal-directed", highlighting the divergent behaviour between those parks respectively self-created and those managed by a coordinator. In order to follow an IS approach and pursue the optimal sustainability performance, a coordinator that manages the relationship among companies and defines which kind of new flow must be exchanged is needed. The need to have a coordinator for the right development of an industrial park has been also justified by an ERA-Net ECO-INNOVERA [13] initiative that analysed more than 160 industrial parks. Inside the project, a deep survey was performed with the aim to identify the main characteristics and most relevant success factors of industrial parks: organizational (governance) and institutional elements emerged as the most impacting (109/168 respondents). Such a coordinating entity usually is either (i) a private or public entity acting as a facilitator or (ii) a public institution interested in the development and management of incentives and policies for the target industrial area. In both cases, the role of the coordinator should be focused on the management of the inter-firm contacts, creation of trust and dialogue among companies, management of joint infrastructures and/or services, recruitment of participating firms. The coordinator is also responsible for the implementation of identified opportunities in order to activate eco-innovation initiatives. In order to accomplish this task, the coordinator should know the inputs and outputs of each company. In this case, a collaborative platform could be used to map the whole amount and type of flows exist in the park.

The involvement of governmental authorities in the park development and operation and the existence of environmental legislation (that's what happens, for example, in the German industrial parks) have been demonstrated of major importance in order to facilitate the achievement of high sustainability performances. A coordinating body is useful in the identification of new streams exchange candidates, in motivating companies to comply with a specific scenario for the benefits of the whole industrial park, and in managing (or supporting in the management of) transactions between involved actors. Considering that "the central barrier to business cases with sustainability relates to the co-creation of private benefits for companies and customers and positive contributions to society and environment – i.e. public benefits" [39], a coordinator has also the role to assure a fair distribution of benefits and costs among participating entities, thus compensating financial losses for any of the involved partner with gains of some others.

A coordinator is thus needed to identify and implement streams exchange opportunities, to supervise their implementation and to motivate the involved companies to pursue sustainability objectives for the benefits of the whole park.

2. Economic-Related Solutions

a) Park and Single Companies Economic Losses

First of all, companies have to follow the market dynamics of the sector they belong to and, as a result, they must look at economic/financial aspects when making IS-related decisions. In fact, companies have the interest to survive against competitors that are usually unaware and disinterested in environmental and social issues. This implies that IS projects are implemented only when a financial gain (for each partner) is achieved, moreover companies select the flow, by-product or resource to be exchanged just considering which one can maximize their profits. This approach is in conflict with (2). For this reason, in order to preserve the economic balance sheet of companies and the survival of the industrial park, it is necessary to introduce two elements, one related the proposed equation and one related to organizational factors.

As mentioned before, the proposed equation lets the possibility to have economic losses. In fact, an optimized solution could include positive environmental and social results but negative economic drawbacks on both companies and industrial park. In order to solve this problem, a constraint should be added to (2) to include that the economic part of the equation will be always higher than 0:

$$s.t.: \quad \sum_{i=1}^{n} eco(i)_t > 0 \qquad i = 1, \dots, n \qquad (3)$$

Thanks to this adjustment, there's no optimal solution with economic losses for the industrial park as a whole, but losses could always occur for one (or more) of the companies involved in the new exchange. In fact, a sustainability optimum scenario from (2) can result in an economic loss for one of the involved companies. Imposing the constraint, the overall (for the park) economic result of the investment is > 0,

thus money can be found from some of the participating exchangers to compensate the economic losses of some others. This could happen as far as the park governance can impose this kind of compensating transactions (1) Organizational-related solution).

b) Management of Infrastructure Investments

In order to create new flow exchanges, independently by the scenario suggested by (2), construction of specific infrastructure (e.g.: new pipelines) could be necessary. This requires that someone pays the investments related to this new facility. To solve this problem, a new tool called *Green Bank (GB)* will be given to the coordinator of the park. The main functions covered by the *GB* are the following: (i) management of the revenues and costs, (ii) calculation of each company investments share, and (iii) provision of support to economic transaction and contract agreements. The mechanism behind the functioning of the tool is here explained. Within a group of companies "asked" to adhere to the optimized behaviours suggested by (2), some companies involved in the new proposed flows exchange configuration get economic advantages, but others could have economic disadvantages. This general situation is represented in Fig. 2, where three companies (B, C, D) have operative gains (OGs) deriving by the implementation of streams exchanges, and one company (A) has to bear operative costs (OCs) for feeding company B. According to (3), the sum of the operative gains is higher than the operative costs. The *GB* is in charge of managing a proper compensation of OGs and OCs among all the involved companies. Focusing on investments, in this example they are fully covered by companies with OGs (B, C, D), while A is not asked to pay for infrastructures. The percentage contribution to the investments of the paying companies is calculated according to (4), considering only the OGs distribution. In Table II, each company's contribution to investments is reported, assuming different OGs for the companies.

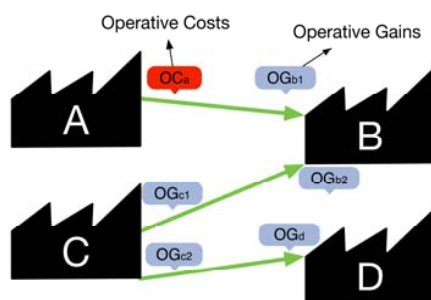$$\%OG_i = \frac{OG_i}{\sum_{i=1}^{n} OG_i} \tag{4}$$

Fig. 2 Group of companies adhering to the optimized flows configuration

Since *OGs* could vary during time, the distribution of investment contributions has to be recalculated and potentially adjusted after a predefined time period.

TABLE II
COMPANIES' CONTRIBUTION TO INVESTMENTS (I = THE TOTAL AMOUNT OF THE INVESTMENTS)

Company	OGs	% contribution	Company contribution
A	0	$\%OG_A = 0\%$	$Contr_A = I * \%OG_A\% = 0$
B	24	$\%OG_B = 30\%$	$Contr_B = I * 30\%$
C	16	$\%OG_C = 20\%$	$Contr_C = I * 20\%$
D	40	$\%OG_D = 40\%$	$Contr_D = I * 40\%$

Thanks to the *GB* tool and the calculation of investments contribution based on (2), companies' competitiveness in their respective markets is preserved and the needed infrastructure investments are carried out with the ultimate goal to maximize the overall sustainability performances of the park.

3. Sustainability-Related Solution

As discussed in §III, sustainability is nowadays a strategic element for manufacturing companies' competitive position. The calculation of the sustainability impacts passes through the LCSA approach. The result of LCSA can be used to compare different scenarios or to support, on a sustainability basis, the decision-making process choosing the best solution towards sustainable production and consumption. Unfortunately, one of the main problems related to LCSA is that its results could be too difficult to understand and interpret. This is due to the fact that they are represented separately in environmental, economic and social impacts. For example, when two different products are compared in terms of sustainability performances, one product can present negative economic impacts but good environmental performances and the other good social and economic impacts but poor environmental performances; the identification of which one is better it is not immediate.

To help the coordinator of the park to efficiently use the proposed approach during the decision-making process, three possible solutions are suggested:

- Converting environmental, economic and social impacts into a normalized or weighted result using decision analysis methodologies such as MCDA or AHP. In this way the coordinator can easily specify coefficients related to the sustainability indicators, using values already defined in literature by LCSA practitioners. This approach is less time-consuming because the coordinator can use the coefficients defined in literature and automatically solve by (2) thanks to normalized environmental, economic and social values. On the contrary, coefficients are usually sector specific (energy sector) and based on personal considerations, thus hardly transferrable from one initiative to another.

- A second approach encompasses the conversion of each indicator in monetary values. In this case, the coordinator can follow the monetization process of the environmental and social impacts proposed in literature (§III). This solution could be very useful for decision makers who are not experts about sustainability. Through the proposed approach, the coordinator can convert (using appropriate conversion coefficient) the sustainability elements of (2) into economic values and decide on which flow exchange

scenario is the best one. This approach allows to easily understand the sustainability impacts and make them readable to all stakeholders. On the contrary, the approach is at a very early stage, studies are not completed and argumentations are not exhaustive. Moreover, identifying the "right" conversion coefficient for each sustainability impact is really hard and questionable.

- In the third approach, coefficients are decided by the coordinator together with the park stakeholders, and the coordinator itself is responsible for the implementation of the desired decision analysis methodologies. In this case, it is very important that the coordinator specifies the criteria considered during the creation of the coefficients. Moreover, as introduced in the first part of this chapter, the coordinator could consider to maximize only the economic part of (2), giving to β more importance than α and γ. Another option is to add the environmental and social parts as a constraint of (2). This situation could also arise as a result of the coefficient decision analysis process, when the coefficient related to environmental and social aspects are very low if compared with the one of the economic aspect. By adopting this approach, the coordinator can personalize the coefficients according to the needs of the specific industrial park and the voice of its main stakeholders. On the contrary, the process of coefficient selection is quite difficult and requires a certain knowledge about decision analysis tools.

Having the possibility to use one of the proposed approaches, the coordinator can easily evaluate the sustainability performance of the scenario resulted from (2). However, the decided weights will be always influenced by the perception that the actors involved in the coefficient decision process have.

VI. CONCLUSIONS AND NEXT STEPS

The proposed study is meant to point out main issues and possible solutions/opportunities for companies interested in the creation of symbiotic flows, pursuing higher sustainability performances not limited to the single companies but for the entire network they belong to. Companies' virtuous behaviours are dependent to gains and losses, but by adhering to the proposed park management practices and adopting the *green back* tool, described in §V, companies' economic losses can be avoided. In sake of this, the discussed approach aims at providing a good starting point to trigger sustainability-conscious decision making in IS initiatives and promote IS projects amongst companies. Further investigations need to be addressed towards policies regulating companies' and parks' sustainability-related actions, as a way to foster IS initiatives intra- and inter- industrial parks.

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