Study of symbiotic flows with economic approach

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STUDY OF SYMBIOTIC FLOWS WITHECONOMIC APPROACH

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ABSTRACT:
At the present, there is a need to give further importance to circular economy and its resulting methods such as the industrial symbiosis (IS), to reduce dependency on raw materials, and to encourage optimal resource use and recycling. That is the reason why, in this paper, we propose an approach to highlight the establishment of an IS in the East of France. We identify potential flows and we study the potential gains obtained under different strategies by participating in the symbiosis. We propose a mathematical model in order to identify for firms involved the interest of the participation in the IS given different costs and earnings, considering economic, societal and environmental impacts. The proposed model is based on an economic approach etc.

KEYWORDS: *Systems modeling, circular economy, industrial symbiosis, economic approach, materials flow.*

1 INTRODUCTION

Sustainability is an elementary issue of natural ecosystems. A highly sustainable ecosystem should be well structured in resource utilization and ecological compatibility (Odum, 1996). As an important component of sustainable engineering, industrial ecology has drawn great attention (Sikdar, 2003). Industrial ecology (IE) is the study of the effect of industrial development, technology, applications, and the associated changes in society and economy on the environment. Industrial symbiosis (IS) is a sub-field of the IE, a discipline emerged more than twenty years ago that studies the flows of materials and energy in industrial and consumer activities as well as their environmental effects. Moreover, it studies the influences of economic, political, regulatory and social factors on these flows (Chertow, 2000).

There is a need to give further importance, to reduce dependency on raw materials, and to encourage optimal resource use and recycling. Industrial symbiosis (IS) has been considered as one of the effective solutions to reduce the impact of waste emissions and primary input consumption moving towards sustainable production models. In fact, IS can be approached from various perspectives (e.g. social, economic, environmental, spatial, organizational, and technical) where case studies (such as eco-industrial parks) are mostly dominating (Boons and Baas, 2006).

In this paper, we describe a part of collaboration with ADEME1which aims implementing a symbiotic project in an industrial area in the east of France (ADEME). The main objective of the project is to design a decision-support tool to facilitate the implementation and management over time of symbiotic flows within this industrial zone. Indeed, for the industrial symbiosis to last, the investment (and its sustainability over time) of each of the stakeholders (companies, government, etc.) is essential. Even if the reasons for this investment over time are diverse, the economic dimension remains a key success factor. That's why, in this paper, we propose an economic approach in order to identify the economic factors allowing for a strong involvement of stakeholders and we focus here on companies (even if the government is considered through fines and subsidies). The proposed mathematical model based on an economic approach is only a small part of the decision support tool that will be defined. As a partnership with stakeholders, this project is carried out within the framework of promoting a circular economic model where nothing is lost, all is transformed.

The paper is structured as follows. In section 2, we highlight the main interests of industrial symbiosis. In section 3, we describe the identification of the symbiotic flows for the considered industrial area. In section 4, we propose a mathematical model based on an economic approach applied to our industrial problem. In section 5, we address a simulation of our proposed model applied on the case of two factories. Finally, we end with a conclusion and perspectives in section 6.

[1] ADEME: is a public establishment under the supervision of the Ministry of Ecological Solidarity Transition and the Ministry of Higher Education, Research and Innovation.

2 INDUSTRIAL SYMBIOSIS

The industrial symbiosis (IS) principles expect that turning waste output from one facility into raw material for another facility will lead to environmental benefits caused by a reduced intake of virgin material and/or reduced emissions (Chertow, 2000).

The economic aspects of the exchange relationships are estimated and discussed as a combination of investments at the time of initiation, and direct and/or indirect economic savings related to upstream or downstream production associated issues. The direct economic savings are usually resulting from avoided discharge fees or disposal costs and from reduced prices achieved by substitution. The indirect economic benefits are related to avoided investments, increased flexibility or supply security. Thus the economic aspects of the IS projects are estimated and discussed as a combination of direct cost reductions. The most important investment is the treatment cost, which gives us multiple investment scenarios and estimated payback times corresponding to the different costs incurred at the project creation time.

An IS approach has several benefits for a company. In the following, we present the relationship between these benefits and their impacts on costs and earnings of a business. A company that adopts industrial ecology practices (such as symbiosis) may have:

- Reduced raw material costs. It is obvious that the costs of extracting raw materials are increasing, hence the increase in purchase prices. The symbiosis proposes a strategy of substitution of these raw materials by others derived from wastes of other companies. In most cases, these wastes are less expensive than the raw materials. The IS promotes sustainable management of raw materials. It allows the company to reduce the quantities of materials used and replace one raw material by another, more sustainable. If well done, this management sometimes allows the company to realize considerable financial gains (Meadows *et al.*, 2004).
- Reduction in management costs for residual materials/savings in disposal costs: Participation in the IS allows companies to sell their industrial scraps (waste, co-products) rather than pay the costs of treatment and disposal of waste, thus achieving a large economic benefit. Indeed the recovery of waste makes it possible to provide reduced prices, which are difficult to obtain in the raw state. This recovery, therefore, has a high added value (Hoornweg*et al.*, 2013).
- Pooling of transport, storage and infrastructure: The IS promotes the pooling of resources. We consider the pooling of transport, treatment or packaging that occurs before reuse of waste by another company, or the pooling of supplies of raw materials and manufactured products. This cooperation also makes it possible to minimize environmental impacts and economic costs.
- Processes number optimization: Waste treatment and disposal methods or extraction of raw materials require a well-defined set of processes, for example the unloading, immersion and burial of waste. Symbiosis can avoid certain processes, thereby minimizing waste treatment costs.
- Improved brand image: The IS favors green marketing which consists in using an ecological approach to improve its brand image. The latter is a crucial point for any business. Being a green business can directly influence the sales number. In fact, when the products and the brand have a positive image, they are more easily marketable and attractive, hence increasing the number of new customers (improving reputation and increasing competitiveness).
- Energy saving: Most of all industrial energy consumption is linked to the extraction or production of basic materials, while only about a quarter is used in processing from raw materials to finished products. On the one hand, the IS reduces the extraction of raw materials. On the other hand, the more the industrial system produces from virgin materials, the more it consumes energy. Alternatively, using residual materials as inputs would save energy by avoiding extraction and transformation operations, which leads to the minimization of the energy used.
- Creation of new employment opportunities: One company's waste may become another's raw material. This exchange can be either direct or through an intermediary, which requires the creation of new job opportunities and sometimes of new business resulting in the reduction of unemployment rate and the improvement of social brand image (Morgan and Mitchell, 2015).
- Reduction of the environmental costs: The symbiosis contributes to the reduction of pollution related to waste and to its landfill since the waste of a company will be recovered and not thrown away. This allows the company to decrease the carbon tax rate as well as increase the financial aid received from the government (Le Moigne, 2014).

We present in this part the hurdles and difficulties generally encountered which can slow down the symbiosis.

- A company can have a resistance to change since changing habits can be a real challenge. The changes in waste management, the introduction of new professional figures, etc. can therefore be a source of anxiety. This can create a brake on real and concrete applications of industrial symbiosis.

- The company must deal with the complexity and number of products flows to be exchanged in the symbiosis, the degradation of the material and the impurity of the by-products used in the symbiotic process. The physical characteristics of recoverable flows can make it impossible to establish a synergy (Adoue, 2007). The conception of certain materials does not allow them to be reused and they are practically impossible to recover, since the separation of their components poses several difficulties and represents significant costs for the company.
- In addition, certain information related to these flows of products or energy exchanged may be critical for a company (confidentiality problem related for example to particular processes used generating waste that may integrate a symbiosis, etc.).
- Achieving synergy between companies depends essentially on their economic interest. The decision to implement a symbiotic flow is based on the relation between benefit and cost. The flow of waste potentially reusable by the companies participating in the symbiosis is also considered as a limit, since it generates additional costs: when the transformation of waste into raw materials requires significant investments (Geldron, 2011).

In what follows, we describe one of the types of symbiotic flow identified

3 IDENTIFICATION OF POTENTIAL SYMBIOTIC FLOWS

In this paper, we consider an industrial zone. This industrial zone is a logistics platform with two industrial activity areas. It is recognized as the most important logistics park in east of France. To date, nearly 120 companies are located there, not only in the sectors of transport and logistics, but also in industrial production and trading, totaling nearly 8,000 salaried jobs. This site is particularly attractive for implementing a symbiotic project. Among the types of flows found, we can cite: wood, aggregates, metals (ferrous metals, non-ferrous metals), plastics (thermoplastics, thermosets), paper, cardboard, edible oils and fats, water, steam and sludge.

In parallel, with the search for flows, we identify the list of companies, existing in this industrial zone. In order to identify the material and energy flows that can be exchanged between these several companies, we grouped them by their activity sectors. Then, based on the collected information, we did a general analysis of each activity sector identified, in order to find its possible INPUT and OUTPUT. Figure1 shows a general overview of the potential exchanges between activity sectors of the considered industrial zone.

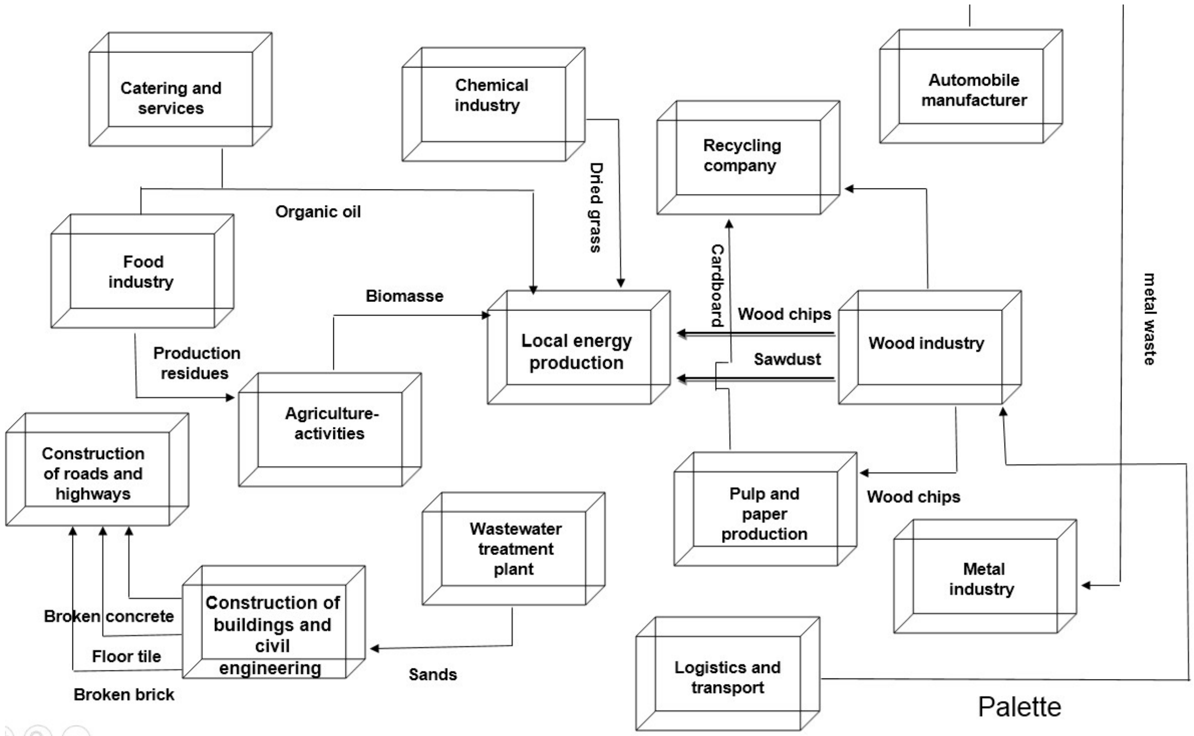

Figure 1: potential exchanges between activity sectors

In this paper, we chose to identify synergies between companies by defining sector of activities. In fact, in similar works, the authors generally adopt an approach based on life cycle analysis (Daddy et al, 2017) (Zang et al, 2017).Although this approach is exhaustive and precise, it requires a lot of details and a huge amount of data. Since we consider an industrial zone with a limited number of companies as well as a sector of activity essentially oriented around logistics (even if it is not the only industrial sector established), our idea in a first step is the classification by sector. By following this methodology, the exchanges with companies become easier and more understandable which will facilitate discussion and companies' engagement around the implementation of the symbiosis.

The concretization of the symbiotic flows is our main objective. Based on the characteristics of this industrial zone, we try to choose the flows having the cheapest costs. This region constitutes a logistics platform, hence the wide use of pallets and cardboard. Moreover, it contains a unit of energy production through the combustion of biomass, which generally comes from wood residues as well as from wood industries. According to all these indicated flows, we design in the figure 2, an alternative circular organization including flows very specific to this industrial zone.

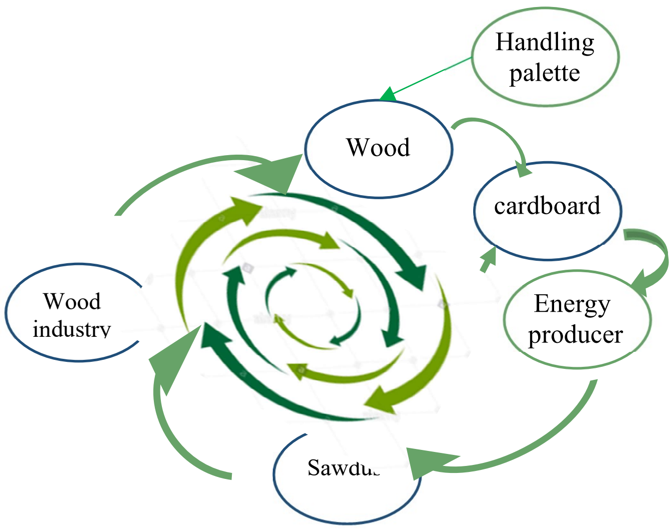

Figure 2: cyclic flows

The establishment of a symbiotic flow changes the organization and logistics of the economic activities concerned. This can generate additional costs but also generate benefits due to the saving of a resource and its substitution and/or pooling. To interest an economic actor, an industrial symbiosis must represent financial added value and must enable this actor to reduce the production costs of a product (Nouinou et al, 2019) (Hennequin et al, 2019). The objective is to promote projects generating a double environmental and socio-economic gain. It is then possible to talk about a win-win solution for the environment (the location and its environmental and social characteristics) and the economy (Dong et al, 2013). the model proposed in the following section allows the evaluation of the economic feasibility which consists in the quantification of the costs and the gains relative to the establishment of a synergy by means of a cost / benefit analysis.

In the next section, we propose a mathematical model studying the interest of each of the companies that participate in the symbiosis, with an economic approach.

It was almost impossible to collect data from companies in the field due to the Covid 19 virus, for this reason the mathematical model presented in this section is only a first version which will be improved after the concrete visits.

4 MATHEMATICAL MODEL

It has to be noted that it was almost impossible to collect data from companies in the field due to the covid-19 virus, for this reason the mathematical model presented in this section is only a first version which will be improved after concrete visits and the complete data collection.

The industrial system considered is represented by a set of *N* factories, which are located in the same industrial zone. Factories will be denoted by i, with $i \in \{1 \dots N\}$. For each of these factories, we have different physical flows of materials and energy, which can be inflows such as raw materials, energy and water (inputs), or outflows, such as heat and water (outputs).Different types of inputs and outputs could be defined such as wood, cardboard, metals, etc., they will be denoted k, with $k \in \{1 \dots K\}$.

We suppose that we have environmental and social costs, which could correspond for example to cost related to carbon or pollutions emissions and cost related to accidents at work, working conditions, etc.

The costs of transport, environmental, social and storage of an INPUT (respectively OUTPUT) k for the factory i inside the IS are given by:

$\boldsymbol{C^k_{trsp,si,input,j}(i), C^k_{env,si,input,j}(i), C^k_{soc,si,input,j}(i)}$ **and** $\boldsymbol{C^k_{stor,si,input,j}}(i)$

(Respectively $\boldsymbol{C^k_{trsp,si,output,i,j}(i), C^k_{env,si,output,i,j}(i), C^k_{soc,si,output,i,j}(i)}$ **and** $\boldsymbol{C^k_{stor,si,output,i,j}}(i)$).

The environmental cost of an INPUT (respectively OUTPUT) k imported (respectively exported) out of the IS by the factory i is $\boldsymbol{C^k_{trsp,ext,input}(i)}$ (respectively $\boldsymbol{C^k_{trsp,ext,output}(i)}$).The social cost of an INPUT (respectively OUTPUT) k imported (respectively exported) out of the IS by the factory i is $\boldsymbol{C^k_{soc,ext,input}(i)}$ (respectively $\boldsymbol{C^k_{soc,ext,output}(i)}$) and the storage cost of an INPUT (respectively OUTPUT) k imported (respectively exported) out of the IS by the factory i is $\boldsymbol{C^k_{stor,ext,input}(i)}$ (respectively $\boldsymbol{C^k_{stor,ext,output}(i)}$).

The cost of an INPUT k, imported from outside the IS by the factory i, is given by $\boldsymbol{C^k_{ext,input}(i)}$, and the cost of

INPUT k, transferred from factory j to factory i is given by $\boldsymbol{C^k}_{\boldsymbol{si,input,j}}(\boldsymbol{i})$.

We suppose that the INPUTs imported from outside the IS are assumed to be ready for use and do not require prior processing (there is no cost of treatment). The cost of processing an OUTPUT (respectively INPUT) k exported from the IS by the factory i is $\boldsymbol{C^k}_{\boldsymbol{treat,si,output,i,j}}(\boldsymbol{i})$ (respectively $\boldsymbol{C^k}_{\boldsymbol{treat,si,input}}(\boldsymbol{i})$).

We suppose that the factory I can apply a kind of internal symbiosis such that it recovers its own waste then reuses them as input. The treatment, handling and environmental costs of a flow k transferred in the internal symbiosis of the factory i are denoted, respectively, by $\boldsymbol{C^k}_{\boldsymbol{treat;int}}(\boldsymbol{i})$, $\boldsymbol{C^k}_{\boldsymbol{manut;int}}(\boldsymbol{i})$, and $\boldsymbol{C^k}_{\boldsymbol{env,int}}(\boldsymbol{i})$. The gain obtained from internal symbiosis related to the flow k for the factory i is denoted by $\boldsymbol{G^k}_{\boldsymbol{int}}$., as shown in the figure 3.

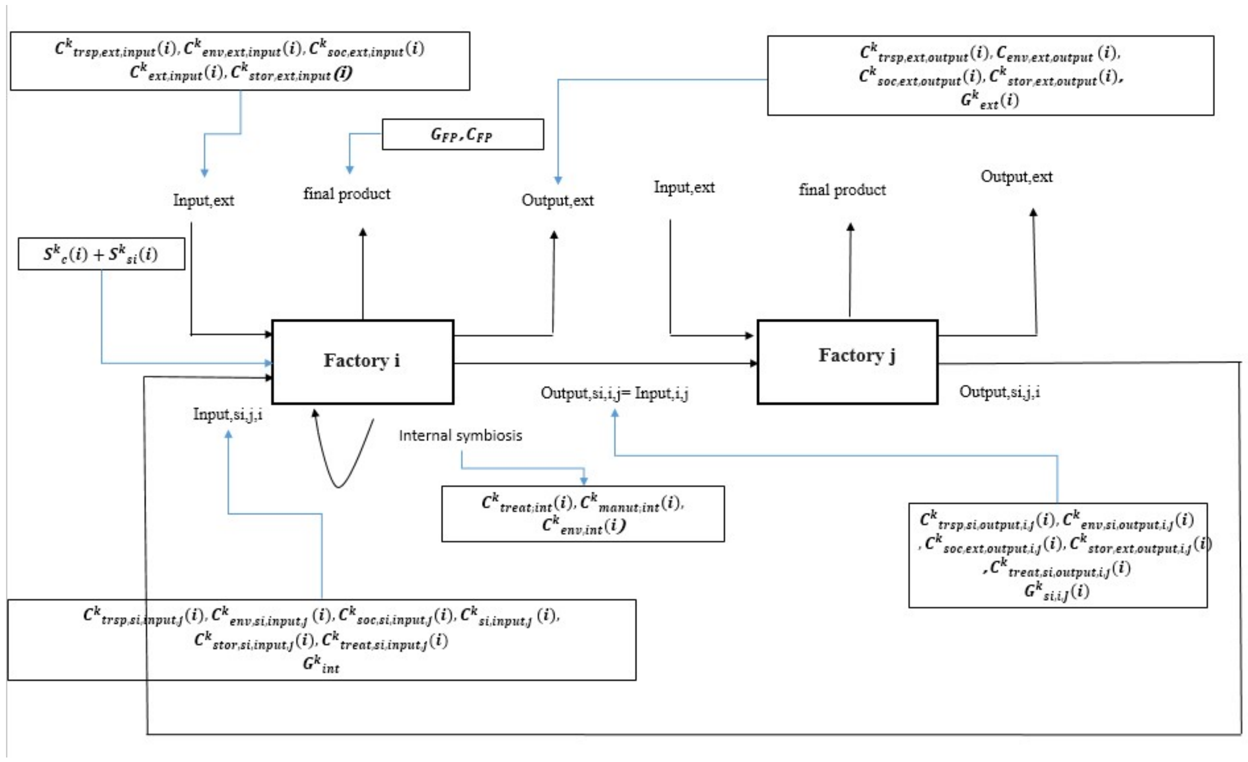

Figure 3: Flow exchanges between factories *i* and *j*

The economic profit of a factory i is denoted by ***P(i).*** The Total gain realized by the factory i is denoted by ***G(i)***. It is given by the sum of $\boldsymbol{G^k}_{\boldsymbol{int}}$,, the sales turnover of outputs outside and inside the IS denoted respectively by $\boldsymbol{G^k}_{\boldsymbol{ext}}(\boldsymbol{i})$ and $\boldsymbol{G^k}_{\boldsymbol{si,i,j}}(\boldsymbol{i})$, the earnings from sales of finished products $\boldsymbol{G_{PF}}$ and the financial aids given by government either when the factory i participates in the symbiosis $\boldsymbol{S^k}_{\boldsymbol{si}}(\boldsymbol{i})$ or not participates $\boldsymbol{S^k}_{\boldsymbol{c}}(\boldsymbol{i})$.

The total cost to be paid by the factory i is defined by ***D(i)*** given by equation (3).It is the sum of the total costs to be paid for INPUTs and OUTPUTs denoted respectively by $\boldsymbol{D_{input}}$ and $\boldsymbol{D_{output}}$, the total cost of internal symbiosis $\boldsymbol{D_{int}}$ and the cost of finished products $\boldsymbol{C_{PF}}$.

The economic profit of a firm participating in the IS is described using equation (1). As noted, it is the difference between the total gain and the total cost of a factory i.

$$\boldsymbol{P(i) = G(i) - D(i)} \quad (1)$$

Such as,

$$\boldsymbol{G(i)} = \sum_{k=1}^{K}[\boldsymbol{G^k}_{\boldsymbol{ext}}(\boldsymbol{i}) + \sum_{\substack{J=1 \\ j\neq i}}^{N} \boldsymbol{G^k}_{\boldsymbol{si,i}}(\boldsymbol{j}) + \boldsymbol{G_{PF}}(\boldsymbol{i}) + \boldsymbol{G^K}_{\boldsymbol{int}}(\boldsymbol{i}) + \boldsymbol{S^k}_{\boldsymbol{c}}(\boldsymbol{i}) + \boldsymbol{S^k}_{\boldsymbol{si}}(\boldsymbol{i})]. \quad (2)$$

Equation (2) describes the total gains made by a company when it participates in the symbiosis.

$$\boldsymbol{D = D_{input} + D_{output} + D_{int} + C_{PF}}. \quad (3)$$

Equation (3) represents the total costs made by a company when it participates in the symbiosis.

$$\boldsymbol{D_{input}}(\boldsymbol{i}) = \sum_{k=1}^{K}[\boldsymbol{C^k}_{\boldsymbol{trsp,ext,input}}(\boldsymbol{i}) + \boldsymbol{C^k}_{\boldsymbol{env,ext,input}}(\boldsymbol{i}) + \boldsymbol{C^k}_{\boldsymbol{soc,ext,input}}(\boldsymbol{i}) + \boldsymbol{C^k}_{\boldsymbol{ext,input}}(\boldsymbol{i}) + \boldsymbol{C^k}_{\boldsymbol{stock,ext,input}}(\boldsymbol{i}) + \sum_{\substack{j=1 \\ j\neq i}}^{N}[\boldsymbol{C^k}_{\boldsymbol{trsp,si,input,j}}(\boldsymbol{i}) + \boldsymbol{C^k}_{\boldsymbol{env,si,input,j}}(\boldsymbol{i}) + \boldsymbol{C^k}_{\boldsymbol{soc,si,input,j}}(\boldsymbol{i}) + \boldsymbol{C^k}_{\boldsymbol{si,input,j}}(\boldsymbol{i}) + \boldsymbol{C^k}_{\boldsymbol{stock,si,input,j}}(\boldsymbol{i})) + \boldsymbol{C^k}_{\boldsymbol{treat,si,input}}(\boldsymbol{i})]. \quad (4)$$

We give in equation (4) the sum of the costs, incurred by the company, of the inflows coming either from outside or inside the symbiosis.

$$\boldsymbol{D_{output}(i)} = \sum_{k=1}^{K}[\boldsymbol{C^k}_{trsp,ext,output}(\boldsymbol{i}) + \boldsymbol{C^k}_{env,ext,output}(\boldsymbol{i}) + \boldsymbol{C^k}_{soc,ext,output}(\boldsymbol{i}) + \boldsymbol{C^k}_{stor,ext,output}(\boldsymbol{i}) + \sum_{\substack{j=1\\ j\neq i}}^{N}(\boldsymbol{C^k}_{trsp,si,output,i,j}(\boldsymbol{i}) + \boldsymbol{C^k}_{env,si,output,i,j}(\boldsymbol{i}) + \boldsymbol{C^k}_{soc,si,output,i,j}(\boldsymbol{i}) + \boldsymbol{C^k}_{stor,si,output,i,j}(\boldsymbol{i}) + \boldsymbol{C^k}_{treat,si,output,i,j}(\boldsymbol{i}))] \quad \textbf{(5)}$$

Equation (5) presents the sum of the costs, incurred by the company, of the outflows coming either from outside ***or inside the symbiosis.***

$$\boldsymbol{D_{int}(i)} = \boldsymbol{C^k}_{treat;int}(\boldsymbol{i}) + \boldsymbol{C^k}_{manut;int}(\boldsymbol{i}) + \boldsymbol{C^k}_{env,int}(\boldsymbol{i}) \quad \textbf{(6)}$$

If there are internal symbiotic flows, the sum of the costs of these flows is denoted by $\boldsymbol{D_{int}(i)}$and is given by equation (6)

The mathematical model is proposed to encourage the concept of IS and especially, to recover waste while ensuring economic gain. The objective of the model is to study the interest that a company participates in an IS. This model is based on the different impacts of the participation in the symbiosis.

In the next section we are going to apply our model in a numerical experiment where we use generic values to acquire new knowledge about our model, and study its behavior.

5 NUMERICAL EXPERIEMENT

In this section, we conduct an experiment drawing inspiration from the considered industrial zone located in east of France. We consider a single flow (*k = 1*), "the wood" which will be exchanged between two factories *i* and *j (N=2)*.

In a general way, participation in a symbiosis generates many changes in costs and earnings for each company.

The symbiosis allows the improvement of the brand image of a company, which allows it to increase its market share as well as its gains of finished product. Table 1 show the impact of symbiosis on the $\boldsymbol{G_{PF}}$ value for the factory *i* going from 600000 to 750000 monetary units.

The IS generates a reduction in green house gas emission and then a reduction in the environmental cost. Industrial symbiosis promotes geographic rapprochement and resources pooling. The latter are relevant solutions for controlling transport costs and minimizing the environmental footprint of actors on the supply chain. It could also create new employment opportunities. Environmental, handling and treatment costs of the internal symbiosis are assumed to be zero. The costs and earnings of each company participating in the IS will vary. These variations are presented in tables 1and 4respectively for factory *i* and *j.*

Table 1: Data associated with the Factory i

Costs/gains	Symbol	Value before symbiosis (i)	Value after symbiosis (i)
Gain finished product	$\boldsymbol{G_{PF}}$	6000000	750000
sales turnover(outside SI)	$\boldsymbol{G_{ext}}$	10000	10000
Classic subsidies	$\boldsymbol{S_c}$	100000	100000
cost of transport	$\boldsymbol{C_{trsp,ext,input}}$	70	60
	$\boldsymbol{C_{trsp,ext,output}}$	80	40
Environmental cost	$\boldsymbol{C_{env,ext,input}}$	3	1
	$\boldsymbol{C_{env,ext,output}}$	3.2	3.2
Social cost	$\boldsymbol{C_{soc,ext,input}}$	1.8	0.6
	$\boldsymbol{C_{soc,ext,output}}$	2	0.8
Storage cost	$\boldsymbol{C_{stor,ext,input}}$	20	18
Cost of external inputs	$\boldsymbol{C_{ext,input}}$	40000	19000
Cost of finished product	$\boldsymbol{C_{PF}}$	660000	570000
Total gain	$\boldsymbol{G}$	710000	1090600
Total cost	$\boldsymbol{D}$	664180	598664,63
Profit	$\boldsymbol{P}$	45820	491935,38

By participating in symbiosis other new parameters appear such as gains from internal symbiosis ($\boldsymbol{G_{int}}$) . In fact by participating in the internal symbiosis, a company recovers its own waste and reuses it as inputs for itself, which generates new gains. Also companies can benefit from subsidies and financial aid from the government. This value, noted $\boldsymbol{S_{Si}}$, is given in the following table by 20000 monetary units for the factory *i*, all the new parameters are listed in tables 2 and 4 respectively for factory *i* and *j.*

Table 2: The values of the parameters added by the symbiosis for factory i

Costs/gains	gains/ costs	values /UM
sales turnover(inside SI)	$\boldsymbol{G_{si,i}}$	30400

Internal symbiosis gain	G_{int}	200
Symbiosis subsidies	S_{Si}	20000
cost of transport	$C_{trsp,si,input}$	1,2
	$C_{trsp,si,ouput}$	29
Environmental cost	$C_{env,si,output}$	0,55
	$C_{env,si,input}$	0,5
Social cost	$C_{soc,si,output}$	0,325
	$C_{soc,si,input}$	0,3
Storage cost	$C_{stor,si,input}$	11,75
Cost of external inputs	$C_{si,input}$	9500

Table 3: Data associated with the Factory j

Costs/gains	Symbol	Value before symbiosis	Value after symbiosis
Gain finished product	G_{PF}	700000	856000
sales turnover	G_{ext}	7000	3600
Classic subsidies	S_c	90000	90000
cost of transport	$C_{trsp,ext,input}$	80	45
	$C_{trsp,ext,output}$	90	34
Environmental cost	$C_{env,ext,input}$	4	1
	$C_{env,ext,output}$	3.5	0.9
Social cost	$C_{soc,ext,input}$	3	0.9
	$C_{soc,ext,output}$	2	0.7
Storage cost	$C_{stor,ext,input}$	35	16
Cost of external inputs	$C_{ext,input}$	3500	1900
Cost of finished product	C_{PF}	500000	427500
Total gain	G	797000	975900
Total cost	D	503717.5s	430328,025
Profit	P	293282.5	545571,975

Table 4: The values of the parameters added by the symbiosis for factory j

Costs/gains	the gains/ costs	values /UM
sales turnover (inside SI)	$G_{si,i}$	6000
Internal symbiosis gain	G_{Int}	300
Symbiosis subsidies	S_{Si}	20000
cost of transport	$C_{trsp,si,input}$	2,2
	$C_{trsp,si,ouput}$	14
Environmental cost	$C_{env,si,input}$	0,5
	$C_{env,si,output}$	0,6
Social cost	$C_{soc,si,input}$	0,6
	$C_{soc,si,output}$	0,425
Storage cost	$C_{stor,si,input}$	4,4
Cost of internal inputs	$C_{si,input}$	760

The chosen values are generic (since the COVID-19 made it difficult to collect the data) and, therefore, the interpretations of the results may change.

According to data presented in tables 3 and 4 and based on the given values, we find that companies with higher earnings are those which participate in the symbiosis.

To study the behavior of our model, we should vary some parameters. Since we are still in the data collection phase, pending verification of our model, we limit ourselves to two variables. We choose to vary the cost of treatment because it is considered as the highest cost borne by the company, when the symbiosis takes place. In fact, most of flows must be transformed to reach the desired quality. These transformations require different technologies, which can be very expensive. However, sometimes the outgoing material flow is perfectly suitable for the second company where the processing cost will be zero. This variation from extreme to extreme justifies our choice. Obviously, the increase in processing costs generates profits for the company. For this reason, we consider the total gains as our second variable.

It is assumed that each increase in the treatment costs is proportional to an increase of the business gains with a coefficient c = 0.02.

Different scenarios are considered and different profit values are obtained by varying the treatment cost in an interval [0, 600000], considering a step of 60000 UM. Figure 4 presents the resulting profit corresponding to the different scenarios.

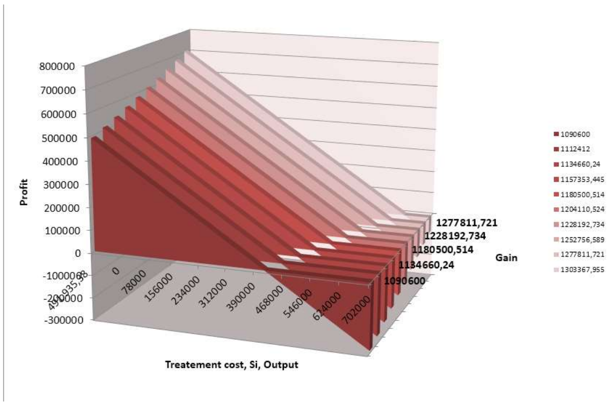

Figure 4: Variations of treatment cost and gain

Figure 4 shows the importance of the treatment cost. By varying the gains according to this cost, we can notice the impact on the profit of the company, which can tip over to have negative values.
I was limited in the simulation because of the sanitary conditions; this simulation will be improved as soon as the data is fully collected

Knowing the importance of the symbiosis in relation with the environment and since the realization of this is not obvious, the proposed modeling highlights direct and indirect impacts such as gains linked to pooling, increased market share (and better brand image of the company), etc. A company can therefore know its economic interest in the event that it participates in the symbiosis. These values can be a motivation to actively participate in industrial symbiosis.

6 CONCLUSION

In this paper, we try to explore the possibilities to establish a symbiosis on an industrial zone in the east of France. For this reason; we identified potential symbiotic flows that could exist between the companies. Then we propose a mathematical model based on economic approach to evaluate the profit of the company and we suggested a first simulation to verify the behavior of our model. We are currently in the data collection phase. As soon as this phase ends, we can check and validate our model.
Our previous works which have addressed IS on the strategic part (Nouinou, 2019) (Hennequin, 2019) focused mainly and the tactical level. The specificity of this paper is that we consider the operational part.

As a matter of perspective, first we will visit all the companies and collect the data necessary to improve our model and rectify it based on these concrete data and interviews. Secondly, even if the participation in the symbiosis seems "easy" and interesting, it is difficult to ensure the sustainability of the IS project. In fact, the difficulty of implementation and the resistance to change are considered as many brakes of real and concrete applications. For this reason, the effective participation of companies in the symbiosis can be partial. So we may consider a second case which represents a degradation of the participation by using for example game theory. We will then be able to define our complete decision-support tool allowing us to integrate different dynamic evolutions and the means to respond to them.

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