Industrial symbiosis as the base for implementing circular economy

A simbiose industrial como base da formação da economia circular

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Maria Lúcia Pereira da Silva³

Abstract
This work evaluated the use of Industrial Symbiosis (IS), and the importance of partnerships, as base for implementing the Circular Economy. For that purpose, action research was used and the stakeholders were grouped in a project called LABMOB. The study analyzed mainly noble wood and its use in furniture. A questionnaire was developed to propose a possible business model. The main results are the closing of cycles and the recovery, with upcycling, of noble wood and a series of other discarded materials, such as metals, in addition of exclusive products, therefore with high added value was obtained. Other advantages are the formation of a wide network that has a micro (designers), meso (national companies) and macro (international organizations) characters. There is also the achievement of an almost spontaneous process that, although initially parasitic, proved to be disjunctive (mutualistic) in the end. For an adequate business model, one must consider reaching an environmentally aware public with good purchasing power, which makes the figure of the designer extremely important. The use of noble wood in such conditions is still scarce, being common only its disposal through burning, to obtain energy.

Keywords: Noble Wood. Upcycling. Mutualistic Industrial Symbiosis. Circular Economy.

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Resumo
Este trabalho avaliou o uso da Simbiose Industrial (SI), e a importância da formação de parcerias, como base para a implementação da Economia Circular. Para tanto se utilizou a pesquisa-ação e as partes interessadas foram agrupadas em um projeto denominado LABMOB. O objeto de estudo foi principalmente a madeira nobre e seu uso em mobiliário. Um questionário foi desenvolvido para propor um possível modelo de negócios. Como principais resultados têm-se a efetivação de fechamentos de ciclos e a recuperação, com upcycling, de madeira nobre e de uma série de outros materiais também descartados, como por exemplo, metais, além da obtenção de produtos exclusivos, portanto com alto valor agregado. Outras vantagens são a formação de uma ampla rede de colaboradores, esta rede tem um caráter micro (designers), meso (companhias nacionais) e macro (organizações internacionais). Além disso, há a obtenção de um processo quase espontâneo e que, apesar de inicialmente parasíco, mostrou-se ao final disjuntivo (mutualístico). Para um modelo de negócios adequado deve-se considerar atingir um público ambientalmente consciente e com bom poder aquisitivo, o que torna a figura do designer extremamente importante. O uso de madeira nobre em tais condições ainda é escarço, sendo comum apenas seu descarte através da queima, para obtenção de energia.


Introduction

A millenary, renewable and environmentally-friendly raw material is wood; it has been used in in the most varied ways, from small objects to gorgeous constructions, in virtually all cultures. However, due to overuse, which has led to endangered or even almost extinct species, in Brazil its commercialization and use must follow strict environmental rules. Thus, currently 2,214 tree species require mandatory licenses and 38 are critically endangered; nonetheless, between 2012 and 2016, 10% of the market share, i. e. 6 million cubic meters, were supplied with these 38 species (FIORAVANTI, 2020). Such a situation requires urgent actions, mainly either closing the production cycles or upcycling discarded material.

In order to close production cycles, Industrial Symbiosis (IS) is a valuable tool. IS definition was reviewed by Mallawaarachchi (2020) and summarized as “a way to transform wasteful industries to closed-loop industrial systems”, the authors also pointed out that there
are three dimensions in the concept: network, context and externalities. Neves et al. (2020) reviewed several case studies and found out that IS actions are spread throughout the world and also that the companies/organizations involved are from the most diverse areas; that is, the existing IS examples show how to close production cycles.

Furthermore, Circular Economy (CE) preconizes the recirculation of resources in production processes and their maintenance in the value-chains. For this, material upcycling is necessary and bilateral, cooperative, symbiotic industrial relations must be established. These relationships not only fulfill the network dimension of IS but also are mutually beneficial from the environmental, social and economic viewpoints. Regarding context, among other things, good communication between potential partners and collective strategies are fundamental (Yazdanpanah, Yazan and Zijm, 2019).

Network and communication also presuppose interactions with several distinct stakeholders and their importance cannot be underestimated. Fischer, Brettel, Mauer (2020) state that in Germany there is co-creation between entrepreneurs committed to the three dimensions of sustainability and stakeholders. To balance multiple objectives, the endorsed strategies are: rejection, similarity and adoption. Thus, stakeholders not only add important value to businesses but also direct them towards more environmentally-friendly situations (Freudenreich, Ludeke-Freund, Schaltegger, 2020).

We therefore aimed to evaluate the importance of partnership formation for cycle closures as regards the use of noble wood and accessories, arising from the disposal of products in the civil construction sector, among others.

**Fundamentals**

For Baldassarre et al. (2019), Industrial Symbiosis is a collaborative approach to obtain competitive advantages, and for that, different industries exchange materials, energy, water and co-products; value is thus generated by a chain of industrial players. This value generation is based on three pillars, technological innovation – mainly through the exchange of waste and energy between players, collaboration, through the identification of relevant stakeholders for implementing the process, and a sustainable business model, hence achieving a new value proposition. An example of the possibility of adding value by IS and design was provided by Ali, Wang, Alvarado (2019); in this case study, metal plates directly recycled from cars destined for recycling were used to produce facades. The advantage of the process is to eliminate the heating cycle to obtain the metal plate, with a reduction in energy consumption.
by 600 MJ/t and, with investment in appropriate design, a 30% reduction in the cost of parts for facades. Still regarding design, Kristensen, Mosgaard (2019), in their review of indicators for the micro level, list 30 indicators as fundamental and categorize them as: RE principles (reuse, remanufacture, reduce, etc.), waste, efficiency, resources, energy, cycles, value retention, system perspective, sustainability and design.

According to Desrochers & Leppälä (2010), neither the concept of IS nor the associated processes are new once the literature has discussed them since the nineteenth century. At that time it was considered rather common and a “spontaneous outcome of market processes”, i.e., a “typical feature of industrial economies”, a way for industrial actors to “internalize their environmental externalities.” Thus, in the authors’ view, it is more advantageous to find spontaneous systems for forming IS than to favor eco-industrial parks. An interesting example is that in Czechoslovakia, where due to labor requirements, Industrial Symbiosis is centuries old, with “towns where coal, steel and cement were produced, some textile mills and other consumer goods industries were often found”. Besides the interconnection among industries, another important aspect of industrial symbiosis defined almost a century ago is the type of relationship established: antagonistic (parasitic) or mutualistic; and for the later disjunctive (reciprocal benefits) or conjunctive (mutually independent). Nonetheless, the authors consider proximity a major indicator to efficiently establish IS.

These perspectives are in agreement with Chertow’s (2000) review, who also pointed out that IS and industrial district literatures are one century old. The author also considers proximity as a prevalent factor due to the high cost of moving, no matter if waste, energy or raw material. However, the formation of virtual eco-industrial parks, called Type 5 model, is also preconized via an expansion of IS benefits “to encompass a regional economic community”. Another important factor that can make IS projects unfeasible is the non-existence of a “continuous process waste streams” or the limited quantity of materials that can be provided. The implementation could be the support for 3 stages: trade of material or already existing energy; organizational relationships and networks formation or the use of “the anchor tenant model”, i.e., one or two large industries provide the necessary critical mass.

ZHANG et al’s (2105) review expanded the notion of virtual eco-parks and industrial symbiosis considering that exchanges among companies, such as materials, energy, waste and even knowledge, can occur over long distances “so proximity is not a precondition for the development of symbiosis”. Furthermore, comparing the existing relationships among species in natural systems, they described industrial parks as dominated by parasitism (companies...
benefit at the expense of others), commensalism (companies benefit from each other’s existence) and mutualism (relationships among companies are beneficial for all of them), it is also possible to consider it as saprophytic (“members engage primarily in reuse and recycling”).

Although there is still no consensus on the definition of Circular Economy, there are three strategies common to all of them: minimization of raw material consumption and waste formation; keeping the resources as long as possible within the system, and reintegration of products into the system at the end of their life cycle. In addition, EC can be considered at three levels: micro – company and its vision of Industrial Ecology; meso – connections between companies and possibly industrial symbiosis; macro – meaning regions, cities, etc. where by collaborative models of consumption can be observed. EC is a regenerative process of production and consumption that allows maintaining the extraction of resources and the generation of waste at viable values for the planet. For that, EC uses closed cycles, which preserve the value of resources and is based on design and education, enabling it to be implemented at any scale (Suarez-Eiroa et al., 2019).

Vanhamäki et al. (2020) provided an interesting example of the use of wood in the implementation of Circular Economy in the region of Päijät-Häme, Finland. The roadmap for the area considered its intense biological flows, since the region annually generates 160,000 tons of municipal waste, 10% of which is of biological origin, in addition to agricultural disposal (animal manure – 800,000 t/year, biomass – 450,000 t/year and 360,000 t/year due to forest/wood management) and biodegradable material from civil construction and demolition. Pulp and paper and furniture industries are other important sources of disposal. This roadmap considered proposals coming from government, industry and academic stakeholders. However, the proposal for wood is just incineration to obtain energy, the greatest advantage of which would only be the decrease in CO2 emissions (~600,000 t/year). Anyway, this research also points out the importance for closing cycles not only for developing industrial symbioses, but also for investing in sustainable technologies and new consumption models. As a counterpoint, Nayha (2019) argues that many stakeholders do not consider sustainable the use of wood to produce bioenergy, mainly because the required large scale of these projects can affect the carbon balance and biodiversity. In addition, this production area is much larger than just obtaining bioenergy, including raw materials for the textile industry, nanofibers, biocomposites, biodegradable plastics, polymers, pharmaceuticals, etc., which translates into opportunities for new small and medium-sized businesses, such as startups, with new models of action, decentralized, based on the area of services, also adding value to
production. A proposal to reconcile different views is a “multifaceted construction”, dependent on the demand of more environmentally correct consumers who see the use of wood as a way of life and are willing to invest in this proposal. In any case, industrial symbiosis would be necessary in this approach.

Germany also has a roadmap based on the use of wood for migration to bioeconomy. The symbiotic action between chemical and wood production industries allowed obtaining high added value products while the life cycle analysis of these products, when compared to the oil industry, indicated mitigation of environmental impacts from 25% to 130%.

In all these works, several players can be observed, each one with different interests and actions in the project development. Silva, Nuzum and Schaltegger’s (2019) review states that there are four reasons for stakeholders to become involved in corporate sustainability issues: a) normative: focusing on societal benefits; b) instrumental: mainly aiming processes measurement and/or evaluation; thus, case studies are an important tool that can drive innovation; c) descriptive, also focused on the issue of innovation and d) social: which favors the search for consensus on the whole. Interviews and questionnaires are common tools to access the opinion of these stakeholders. In terms of communication, emphasis is placed on the need to have transparent, reliable and comprehensible information, preferably quantitative, that is, clear indicators are needed. In addition, five groups of stakeholders are considered fundamental: employees/collaborators, consumers/customers, suppliers/other players in the value chain, community and society. In Ghana, Danso et al. (2020) indicate that the integration of the various stakeholders and organizations favors the competitiveness and financial conditions of small and medium-sized companies strongly orientated towards sustainability. Blomsma, Pigosso, McAlone (2019) suggest co-design, in which the company initially develops its vision and later involves new stakeholders, achieving competitive advantage from collaboration.

**Materials and Method**

This work is an exploratory and applied research that uses action research method to characterize a set of actions and interactions promoted during a Circular Economy project. The project, named LABMOB, was supported by Istituto Europeo di Design, via Research Center (Cried), YVY Reciclagem and Enel Distribuição São Paulo.

Tripp, in his emblematic review of the action research concept, contrasts the use of a generic definition, such as “identification of strategies of planned action which are
implemented, and then systematically submitted to observation, reflection and change”, with a pragmatic approach, i.e., “a form of action inquiry that employs recognised research techniques to inform the action taken to improve practice”. In addition, he also indicates that the main characteristics of this form of research are: innovative, continual, pro-active strategically driven, participatory, interventionist, documented among others. Nonetheless, one of its limitations he indicates is “it is not possible to pre-specify either what knowledge will be gained or what practical outcomes will be achieved because the results of each cycle will determine what happens next, and there is no saying at the outset where the process will lead”. (TRIPP, 2005). Moreover, Santos, Calíope and Barros Neto (2017) also pointed out some other characteristics, such as: to be empirical, done by the practitioner but presenting the formal requirements of one academic work, and conceived and carried out in close association with the resolution of a collective problem in which participants representative of the situation are involved in a cooperative way.

This work is therefore considered an action research because, in addition to the direct involvement of the researchers in each stage of the work, purposing to describe the existing interactions between all the stakeholders, it is a collaborative situation, in a project that presupposes proactive attitudes of all the people involved in the solution. The project “problem” is of industrial nature: the disposal of discarded material, especially wood.

Almost simultaneous to the project development, an internet survey was developed and applied for investigating the perception of consumers regarding the acquisition of sustainable products, such as those produced at LAB MOB. The questionnaire was applied via social media, such as LinkedIn, Facebook, WhatsApp, etc. The questionnaire link was also sent by email to as many people as possible; the intention was to be random and 62 valid responses were obtained. The research raised several distinct dimensions; for each dimension, several statements were established, as follows.


S2 - Product Design dimension: 10 statements, based on previously discussed theoretical indicators (Fundamentals, item 2).

\(^4\) https://www.imaflora.org/

Table 1 shows some examples of statements offered to the questionnaire respondents. The data obtained was analyzed using non-parametric statistics and the Likert Scale, in which a numerical value from 0 to 6 was given to each response option, as shown in Table 2. (CORDER, G. W.; FOREMAN, D. I, 2014). For results analysis, some correlations were sought to investigate the purchase intention regarding product design and business model. Thus, the assumptions are:

C1: INFLUENCE OF YEARS OF STUDY: greater number of years of study, higher level of environmental awareness;

C2: INFLUENCE OF INCOME RANGE: people with higher incomes have greater environmental awareness;

C3: INFLUENCE OF LOCATION: people residing in more industrialized regions show greater environmental awareness;

C4: INFLUENCE OF ENVIRONMENTAL AWARENESS: people with a higher level of environmental awareness tend to adhere to new business models;

C5: INFLUENCE OF ENVIRONMENTAL AWARENESS: people with a higher level of environmental awareness understand the importance of product design.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>PI</th>
<th>PD</th>
<th>BM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I try to be informed about the environmental risks of the product before buying it.</td>
<td>I prefer products with a design that can be fixed or updated.</td>
<td>I prefer a product to become a service. Nike recently released subscription sneakers for kids in the US. You get two pairs a month and as the child grows, you return the shoes to Nike and get new pairs. (<em>design as a service</em> - IDEO).</td>
</tr>
<tr>
<td></td>
<td>I seek to buy products made from recyclable materials.</td>
<td>I prefer products that can be rented, or I borrow things I use infrequently, rather than buying them.</td>
<td>I prefer a product to become a smart service. Bundles uses Internet of Things (IoT) technology to provide customers with a pay-per-wash service in washing machines. Monthly fee is retrospectively adjusted based on actual usage data (<em>embedding intelligence</em> - IDEO).</td>
</tr>
<tr>
<td></td>
<td>I prefer to buy products that can be recycled later.</td>
<td>I prefer product design based on materials that would otherwise be discarded.</td>
<td>I prefer products with greater durability. Caterpillar offers rebuild and remanufacture of engines and other parts. (<em>life extension</em> - IDEO).</td>
</tr>
<tr>
<td></td>
<td>I prefer to buy products with quality seals (PROCEL, FSC, INMETRO, IBD, among others).</td>
<td>I prefer that the product design incorporates recycled materials.</td>
<td>I prefer companies that care about packaging. Splosh customers sign up to receive sachets of concentrated cleaners that dissolve safely as part of the product or can be sent back for refills (<em>smart materials choice</em> -)</td>
</tr>
<tr>
<td></td>
<td>If I know the negative environmental impact of a certain product, I do not buy it.</td>
<td>To avoid waste, I try not to buy large quantities of a product on sale, unless I have the real expectation of using it in the short term..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To avoid waste, I try not to buy large quantities of a product on sale, unless I have the real expectation of using it in the short term..</td>
<td></td>
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</tbody>
</table>

⁵ www.circulardesignguide.com
IDEO). I prefer companies that offer collect/return of products. Desso offers customers the service of collecting carpet tiles for manufacturing new ones. (IDEO - take back).

I prefer companies that offer modular products. Fairphone’s mobile modular design and replacement parts make it easy for anyone to repair them, allowing the phones to last as long as possible. (IDEO – modularity).

<table>
<thead>
<tr>
<th>Table 1 – Statements for Purchase Intention (PI), Product Design (PD) and Business Models (BM) dimensions</th>
</tr>
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<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Does not apply/I don’t know</td>
</tr>
<tr>
<td>1</td>
<td>Totally disagree</td>
</tr>
<tr>
<td>2</td>
<td>Disagree</td>
</tr>
<tr>
<td>3</td>
<td>Partially disagree</td>
</tr>
<tr>
<td>4</td>
<td>Partially agree</td>
</tr>
<tr>
<td>5</td>
<td>Agree</td>
</tr>
<tr>
<td>6</td>
<td>Totally agree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2 – Likert Scale used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source: The authors.</td>
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</table>

## Results and Discussion

This section describes the project itself and thereafter the steps taken, their respective evaluation and ulterior optimization. The feedbacks obtained, both internally and by questioning potential consumers, are also presented.

### 4.1 LABMOB Project

In its first phase, the project lasted 10 months and, as aforementioned, involved the decision of three important international players: Cried, YVY Reciclagem and Enel. Whereas Cried promoted this project among several stakeholders, being responsible for assembling multidisciplinary teams, YVY managed the processes and Enel provided the co-products for the Industrial Symbiosis.

Among other things, CRIED develops tailor-made projects by the systemic approach to design to promote not only innovation but also the creation of new businesses. To this end, it interacts with private and public companies and the third sector.

YVY specializes in recycling ferrous metals in Brazil, linking suppliers of co-products, to value them economically, and customers, to whom it ensures the provision of recycled raw materials in a reliable and legal way. In addition, it promotes educational actions on the importance of recycling, and is concerned with reducing the consumption of inputs, mainly water and energy; therefore, the company respects the three pillars of sustainability.
Enel is the largest private company in the electricity sector and develops renewable energy sources while operating throughout the chain, from generation to commercialization. Its commitment to the three pillars of sustainability has earned it numerous awards, such as “Most Sustainable Company of the Year” in 2018 “National Innovation Award” in 2017 and so on.

Participation in the project occurred from invitations, which involved the direct participation of one of the authors of this work. Due to the expertise of the organizations involved, the project also trains people to undertake in the sustainable products market. The main action to be developed was use with upcycling, which means revaluing the co-product, of mainly wooden crosspieces from electricity poles that had been discarded, and reinserting them, by closing the cycle, in the consumption of goods.

4.2 Project Stages and their Respective Evaluations

One characteristic that was evident from the beginning was the interest of designers in the opportunity, since there is a critical mass for development with this approach. Thus, of the 120 people invited to launch the project, 60 were interested in participating and 47 were selected, with profile matching, i.e., without gender issues.

LABMOB has three distinct stages: a) identifying and validating the problem; b) developing and validating the solution and c) designing and validating the business model. To assist in the execution of these stages, five master classes were carried out, focusing on: solid wood, furniture and lifestyle; creative economy; entrepreneurship; marketing and distribution and new collaborative network businesses.

The description of the problem implies working with very different material, since the wood discarded from the poles by Enel and stored by YVY is old, marked by time, weathering, with holes and cracks, of most different species, little known at first sight, but of high density and stability. Tools had to be developed and specialists tried to determine the species, which could add greater value to the product and it was up to the designers to transform the “defect” into an attribute, for it to become a virtue.

The next step, prototyping, favored partnerships between project members; in addition, it was possible to obtain products that comply with the Design for X criteria. The products created are long-lasting, modular, easily assembled and disassembled, remanufactured, and

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obtained by recycling, that is, with less consumption of resources, especially virgin raw material. Examples of this approach are the production of furniture without glue, just screws and fittings; Figure 1 presents typical results. The furniture designed and built used pre-existing holes in the wood, making it very efficient in terms of energy consumption. The material produced was part of an exhibition, sponsored by LABMOB players, and great interest was observed in the public that attended the event.

![LABMOB products](Image)

**Figure 1 – LABMOB products**
Source: The authors

### 4.3 Questionnaire Analysis

Even intending to randomly obtain a sample, a respondent profile could be observed: female gender, average age of 29.2 years, 18.8 years of study, monthly income of R$11,650.53 and predominance of Southeast residents, which may indicate a tendency towards a higher level of environmental awareness in the more industrialized regions of the country. There is thus an indication of a correlation between the first three variables (C1, C2, C3), suggesting that people with a higher educational and social level have a higher level of environmental awareness, but it also demonstrated a difficulty in having more respondents from other regions or with lower purchasing power.

As for the Purchase Intention dimension (PI) and environmental awareness (C4), the general average of respondents agree (5, Likert Scale) with purchasing more sustainable
products that take environmental risks into account and, whenever possible, purchase products that are made from recyclable materials or that allow recycling them later; moreover, they also care about quality seals. Another trend is that consumers would buy products with less environmental impact regardless of the price; they would choose products whose companies offer collection service, and would buy semi-new products.

As for the Product Design dimension (PD) and environmental awareness (C5), the general average of the respondents partially agreed (4, Likert Scale) that design has an influence on the conception of products, and they would opt for products that: allow repairs or “upgrades”, incorporate recycled materials, have modular dimensions and are easy to assemble/disassemble, besides allowing combinations as needed. Therefore, they would rent or borrow products that they do not use frequently and the tendency is to accept products that become a service. However, the responses also pointed out that consumers are still more concerned with beauty and comfort, which suggests a lack of understanding of product design in its creation.

In the Business Models (BM) dimension, the overall average of respondents strongly agreed (6, Likert Scale) and showed interest in products that allow for an extension of their useful life; they are concerned with packaging, i.e., there is a strong tendency towards recycled or biodegradable packaging. Furthermore, also in this dimension, adherence was reinforced to products that become services and that can be combined with the Internet of Things (IoT), such as subscribing to laundry services.

Table 3 shows the values of medians (wilcoxon), modes, means and total percentage for each dimension. The median indicates that there is indeed an intention to purchase sustainable products and that new business models are widely accepted, but product design is not considered relevant.

<table>
<thead>
<tr>
<th>Dimensions General</th>
<th>Median</th>
<th>Wilcoxon*</th>
<th>Mode</th>
<th>Mean</th>
<th>% Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase Intention</td>
<td>5.0</td>
<td>n/a</td>
<td>5.0</td>
<td>4.4</td>
<td>73.5%</td>
</tr>
<tr>
<td>Product Design</td>
<td>4.0</td>
<td>n/a</td>
<td>4.0</td>
<td>4.2</td>
<td>70.6%</td>
</tr>
<tr>
<td>Business Models</td>
<td>6.0</td>
<td>n/a</td>
<td>6.0</td>
<td>5.2</td>
<td>86.8%</td>
</tr>
</tbody>
</table>

* Wilcoxon – used if median is 0.5. Source: The authors.

Table 4 presents the Spearman correlations between all dimensions; Table 5 shows the level of correlations and Table 6 provides legend for interpreting the correlations. The results show that there is a moderate correlation between the dimensions of Purchase Intention and Product Design, which indicates that products with eco-design, as exemplified in Table 1 and
in the text, are important. The dimensions Purchase Intention and Business Models were found to present a weak correlation, which may indicate a lack of clarification regarding the advantages of new business models. Other evidence relates the Business Models and Design dimensions, showing a very weak correlation, which indicates that there is consent to the understanding of the respondents that products become services; yet it demonstrates a lack of understanding of the impact that product design has in the creation and innovation of these business models. This observation is reinforced by the weak connection between DP and MN; the respondents consider that changes in the production system would already be enough to make the activity sustainable, which means they do not infer that just keeping the current system actually hinders circularity.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>PI</th>
<th>PD</th>
<th>BM</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>1.00</td>
<td>0.540</td>
<td>0.357</td>
</tr>
<tr>
<td>PD</td>
<td>0.540</td>
<td>1.000</td>
<td>0.173</td>
</tr>
<tr>
<td>BM</td>
<td>0.357</td>
<td>0.173</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Table 4 – Spearman’s Correlation coefficient
Source: The authors.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>PI</th>
<th>PD</th>
<th>BM</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>1.00</td>
<td>M</td>
<td>W</td>
</tr>
<tr>
<td>PD</td>
<td>M</td>
<td>1.000</td>
<td>VW</td>
</tr>
<tr>
<td>BM</td>
<td>W</td>
<td>VW</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Table 5 - Spearman’s Correlation levels
Source: The authors.

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Correlation level</th>
<th>Acronym</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 to 0.19</td>
<td>very weak correlation</td>
<td>VW</td>
</tr>
<tr>
<td>0.20 to 0.39</td>
<td>weak correlation</td>
<td>W</td>
</tr>
<tr>
<td>0.40 to 0.69</td>
<td>moderate correlation</td>
<td>M</td>
</tr>
<tr>
<td>0.70 to 0.89</td>
<td>strong correlation</td>
<td>SC</td>
</tr>
<tr>
<td>0.90 to 1</td>
<td>very strong correlation</td>
<td>VS</td>
</tr>
</tbody>
</table>

Table 6 - Correlation coefficient - legends
Source: The authors.

Conclusions

This work presented how a project involving several different stakeholders can close the noble wood production cycle. The greatest advantage of this project lies in upcycling, as several discarded materials are valued, not only wood. In addition, the project brought opportunities for various stakeholders, including furniture designers, not only to work with a noble raw material, but also value it by design, and the entry into a process of Circular
Economy and Network Entrepreneurship. Particularly, the existence of the IED - YVY partnership was fundamental, while the IED is supported by a network of professionals and different environments, mainly scholars and university, YVY provides the business environment for stakeholders mediation, having meaningful know-how in collaborative projects. Moreover, the three dimensions, as postulated by Mallawaarachchi (2020), were achieved. The network formed was broad, the work context corresponds to industrial symbiosis and circular economy very well applied and several distinct externalities were met.

Desrochers & Leppälä (2010) described IS as a “spontaneous way of market process” and the present case can hence be characterized as an almost spontaneous process. IS could be parasitic, as this case could initially be defined, but also it was disjunctive (reciprocal benefits) and favored by the proximity of designers and raw material. However, a “virtual” proximity is possible and sometimes occurred, with a foreign scholar being able to coach.

Thus, obtaining Industrial Symbiosis did not prove to be a limiting step in closing the cycle, but rather very effective. The fact that the material has unique characteristics makes the business model more challenging, as verified by the answers to the questionnaire. It will thus be up to the LABMOB project participants to develop actions to clarify potential consumers about the importance of project design. Design often proved to be an issue. Ali, Wang, Alvarado (2019) state that design proved IS and also among the 30 indicators proposed by Kristensen; Mosgaard (2019) design is one of them. IS proved to be a meaningful base for EC implementation since EC means resignification and that occurred with the planned furniture produced, which also meant added value and exclusivity regarding the final product.

The observations made in this research are well supported by the references, as reported in Fundamental (Section 2). The work therefore has a micro character when it addresses designers, meso when it places important companies as partners and regional when international organizations collaborate in development. In addition, the importance of design and, indirectly, of education, was observed due to the need for better understanding the importance of design in the project and, consequently, the development of the business models. These findings are in line with the definitions of (Suarez-Eiroa et al. 2019).

As Baldassarre et al. (2019) stated, for Industrial Symbiosis to be effective, it needs innovation, which was observed in this case, with this innovation being more of an approach than a technological one, of collaboration, as clearly occurred, and of a business model, as this work proposed. Furthermore, many of the indicators proposed by Kristensen; Mosgaard (2019) were met in this research.
Several stakeholders participated in the process and, as commended by Danso et al. (2020), the integration of these various micro-entrepreneurs and designers ensured the competitiveness of the work. However, examples of sustainable use of wood, in closed cycles and dependent on bioeconomy, are still scarce, and its destination to obtain energy is common. This work can therefore indicate some alternative ways for employing this noble material.

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