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# Implementing Do-It-Together: The Cross-fertilization of Do-It-Yourself and Open Manufacturing[1]

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## ABSTRACT

Nowadays, the emergence of digital technologies offers consumers access to customized products to meet their individual needs. Unlike traditional manufacturing, social manufacturing facilitates this by involving consumers in the design and production processes, which requires a paradigm shift. It is characterized by the central role of the consumer in the manufacture of their own product and the use of the cyber manufacturing space to ease exchanges between different groups of individuals. Social manufacturing can rely on

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the Do-It-Together (DIT) paradigm to achieve this goal. In the absence of a precise definition, this article aims to define DIT by integrating the principles of Do-It-Yourself (DIY) and open manufacturing and to formalize the DIT method for its operationalization, based on a review and analysis of the literature.

**KEYWORDS:** Do-It-Together, Do-It-Yourself, Social Manufacturing
**JEL CODES:** O31, O32, O33, O35, O36

As a result of growing prosperity and digitization, citizens and consumers are increasingly paying attention to the services that companies can provide for them. In many sectors, consumers are looking for products that they can customize to meet their individual needs. Access to technologies related to Industry 4.0, such as the Internet of Things (IoT) or cyber- physical systems, gives manufacturers the opportunity to gain access to consumer needs, but they cannot yet fully exploit this potential and benefit from mass customization (Wang *et al.,* 2017). Moreover, through these technologies, citizens seek to become increasingly involved in the production of their products. As such, manufacturers are faced with two major difficulties: (i) a lack of tools to understand the needs of citizens in order to respond to them effectively, and (ii) traditional manufacturing methods that are poorly adapted to mass customization strategies.

In this context, new manufacturing methods have emerged, such as the social manufacturing concept. It is defined as a new mode of manufacturing, in which consumers are fully involved in the production process via the Internet (Shang *et al.*, 2013). As a result, it is an open, more democratic way of manufacturing, because individuals (particularly consumers) are involved in the design process. Social manufacturing also introduces new strategies to design products and/or services. These include Do-It-Yourself (DIY) to foster new forms of creativity and Do-It-Together (DIT) which leads to the emergence of new communities (Hirscher *et al.*, 2018).

DIY is defined as a "*method to build, modify or repair things without the direct help of experts or professionals*" (Bonvoisin *et al.*, 2016). It is attracting growing interest and is inspiring new ways to support the ability of non-expert citizens to produce complex, high-quality products. DIY promotes technological awareness and the production skills of citizens. It gives them access to reliable means of production (Bonvoisin *et al.*, 2017) thanks to innovation spaces such as fabrication laboratories (fablabs), or the workshops of manufacturers. DIY is thus an approach that encourages consumers to design and produce a product and/or service themselves. Moreover, it allows them to share design knowledge with other consumers through communities of makers and/or within innovation spaces. The DIY movement has therefore promoted a flexible and agile type of manufacturing dedicated to individual manufacturers, mainly with a view to increase sustainability, and with little involvement of companies.

DIT is not yet clearly defined in the social manufacturing literature. Works which have studied it emphasize that DIT is inspired by the DIY movement; however, they have not made a clear distinction. Indeed, according to Xiong *et al.* (2017), DIT appears to be a more collaborative method. It goes beyond the artisanal aspect of DIY and it triggers a mode of social manufacturing which involves the consumer, businesses, as well as other specialized stakeholders, leading to the development of co-created and distributed value networks. In this context, this article focuses on this potential innovative and collaborative production mode for companies. This study proposes a definition of DIT as well as an organizational framework for this method in order to offer perspectives for its concrete implementation in an industrial context.

The paper is organized in three parts. The first section provides an overview of the concept of social manufacturing and the alternative design strategies which are emerging with this new mode of production. Among these, the paper will focus on the DIY and DIT strategies and their distinctions. A definition of DIT will be proposed. In Section 2, based on the works on social manufacturing and open manufacturing, this study proposes an organizational framework to provide the foundation for the future implementation of DIT. Finally, in Section 3, the importance of demonstrating the feasibility of DIT is discussed.

## Do-It-Together: An Approach to Rethink Social Manufacturing

Although the DIT approach is largely based on the concepts of social manufacturing and the DIY method, there is no precise definition that allows companies to implement it in practice. Thus, this section aims to define DIT and specify the key processes.

### Overview of the Concept of Social Manufacturing

Faced with the growing trend of personalization, new manufacturing methods are emerging. Among these, the paradigm of social manufacturing can be seen as a more open and democratic approach to traditional manufacturing. It involves different levels of user participation in the production process (Shang *et al.*, 2013; Hirscher *et al.*, 2018).

This paradigm states that consumer demand may be better satisfied as consumers get closer to the profile of producers, playing the role of a prosumer (Toffler, 1980; Ritzer, Jurgenson, 2010). Involving consumers strongly impacts traditional production methods of products and/or services by companies. Indeed, social manufacturing requires the creation of a new environment where physical manufacturing facilities, capacities and social factors are integrated in a cyber manufacturing space (Xiong *et al.*, 2017). It shares commonalities with the peer-to-peer model in computing, such as social/relational dynamics, open collaboration and value creation in the form of shared resources (Bauwens *et al.*, 2019). Some initiatives, such as Sensorica[2], already illustrate this type of alternative model by creating or contributing to *open and collaborative projects*, *crowdsourcing* resources, and harnessing *collective intelligence*. Consumers can then manage resources and socialized manufacturing activities distributed through online digital spaces to facilitate real-time personalized and socialized production (Mohajeri *et al.*, 2014; Jiang *et al.*, 2016b). Social manufacturing has recently been trialled in the fashion industry. Collaboration in small-scale garment production allowed consumers to be involved in different stages of the production process, while creating new innovations in design and manufacturing (Hirscher *et al.*, 2018).

According to Jiang *et al.* (2016c), social manufacturing is a social and sustainable paradigm for mass individualization thanks to a cyber-physical-social space that allows decentralized prosumers to co-create fully customized products and services (Jiang *et al.*, 2016a). This cyber-physical-social space fosters collective human intelligence and social organizations through communities giving rise to professional or non-interdependent consumer dynamics with a common purpose. Social interactions establish processes by which prosumers act and react with each other. These social interactions are characterized by demands, preferences, situations or experiences, all prerequisites to establish collaborations between prosumers. It should be noted that a representation of the personalization process specific to social fabrication is proposed in the research of Jiang *et al.* (2016c).

Social manufacturing illustrates a new way of producing. This approach integrates the end user as a co-creator of value through alternative design strategies which allow various types of value creation, beyond monetary benefits (Hirscher *et al.*, 2018). Indeed, alternative design strategies related to

2. Sensorica is a pilot project for crowd-based peer production applied to hardware. It proposes an environment dedicated to synergistic open innovation, leveraging collective intelligence – https://www.sensorica.co/

social fabrication aim to involve the individual in the manufacturing of their own objects and thus potentially remove the need and desire to consume through creative and social experiences (Chapman, 2005). Three alternative design strategies can be identified: halfway/participatory design, Do-It-Yourself (DIY), and Do-It-Together (DIT) (Hirscher *et al.*, 2018). Halfway/participatory design involves the user in the design process, resulting in unfinished objects. It gives the user the opportunity to experience co-creation by letting him partially participate in the fabrication of the object while enjoying learning new knowledge and skills (Fuad-Luke, 2013; Hirscher *et al.*, 2018). The DIY and DIT methods are presented by the authors as a form of production that allows the consumer to fully participate in the creation of an object. Taking the form of workshops and DIY kits or instruction manuals, these practices allow consumers to fully participate in production. DIY and DIT generate new values thanks to the positive creative experiences they create: they offer the opportunity to acquire new skills who will benefit the users.

The identification of these strategies focuses not only on the consumer-user but also on other types of users such as entrepreneurial users and peer-to-peer networks. This highlights a new dimension of the "social" aspect of social manufacturing, hitherto little addressed in the literature (*e.g.*, Jiang *et al.*, 2016b). Indeed, according to Hirscher *et al.* (2018), the formulation of the term social manufacturing has mainly focused on digital personal manufacturing, or on a larger scale, mass customization and distributed manufacturing. In this context, the term "social" refers to social networks (*e.g.*, Facebook, LinkedIn) as a facilitating means of interaction and communication with users (Zhou *et al.*, 2016). However, the potential for localized social interaction at the small local scale of a manufacturing ecosystem is overlooked. Therefore, based on participatory clothing workshops (participatory or halfway clothing) involving 120 participants at a small local scale (in several different cities), the work of Hirscher *et al.* (2018) focused on the localized social dimension by observing the different values generated by these strategies (economic, social, environmental, knowledge, and emotional values).

This work aims to be in line with previous works, in particular those of Hirscher *et al.* (2018). The objective is to highlight a new aspect which has not been addressed thus far. We focus on the manufacturing dimension and the localized social interaction with customers and between the manufacturers and the industrial world that characterize social manufacturing. This manufacturing dimension deserves to be better studied. Indeed, social manufacturing is based on a logic of networked manufacturing. It is characterized by an integrated and centralized system (centralized crowdsourcing): "*a kind* *of configuring, running, maintaining and managing a huge number of geographically distributed socialized manufacturing resources in the form of manufacturing community network, through both public and professional networked online platforms, to finish partial or the whole production tasks for enterprises which want to produce real products on the basis of outsourcing or crowdsourcing service mechanisms*" (Jiang *et al.*, 2016b, p. 12). Each manufacturer interactively communicates with its customers (through centralized crowdsourcing) and involves them in the design processes to co-create innovative products and services (Li *et al.*, 2018). But the interaction between manufacturers remains limited. The logic of networked manufacturing refers to the social networks of customers. In particular, manufacturing firms are connected via traditional contracts within the same supply chain. However, the future social manufacturing ecosystem is expected to be highly connected (Li *et al.*, 2018). Manufacturers should adopt a decentralized and distributed open-manufacturing system based on knowledge and service sharing to help raise the level and quality of the entire industrial system (Tseng, 2014; Li *et al.*, 2018).

In this context, we are particularly interested in the notion of DIT, which has remained close to the definition of DIY until now. However, due to its collaborative dimension, DIT highlights a promising alternative mode of production that is not only user-oriented but also considers designers and producers (companies and manufacturers) as well as their interactions in their localized cocreation ecosystem. Combining DIY practices with open industrial modes of production under the DIT approach may bring about a change of perspective: it may transform traditional production systems into modes that are more in line with consumer needs at different levels (personalization, local scale and proximity of users, ecological commitment…) generating many new shared values.

## Do-It-Together: From Co-Creation to an Open-Manufacturing Process

This work reviews the literature to conceptualize DIT. This approach, which combines participatory design and collaborative production, gives rise to a mode of manufacturing based on a high involvement of consumers during manufacturing who are linked to a set of manufacturers in an open and distributed social manufacturing network. We thus argue that DIT is based, on the one hand, on DIY methods to emphasize the involvement of consumers in the co-creation phases with manufacturers, and, on the other hand, on open-manufacturing approaches describing interactions between firms in open networks connected to a community of consumers within a social manufacturing ecosystem.

### *A Co-Creation Approach Based on the Do-It-Yourself Method*

The participatory design method which characterizes DIT is inspired by the DIY approach which consists of flexible and agile manufacturing dedicated to individual makers. DIY is "*a democratic design process of self-directed amateur design and production activity, carried out more closely to the end user of the product created*" (Atkinson, 2006, p. 1). Today, DIY has grown into a popular movement of prosumers, relying on communities which share common practices and values (Dupont *et al.*, 2017).

DIY aims to provide an answer to the consumers' need for customizable products or parts in the age of mass consumption, in order to address a perceived lack of service quality and product availability, as well as the limited opportunity for participation in customization offered by companies. The stake for more customization is all the more important because it allows consumers to take ownership of their environments differently, developing more respect and ethics in their lives, which is a key decision factor for the preference of a DIY product (Wolf, McQuitty, 2011). Finally, the DIY approach appears to be a way to control the customization process by offering customers the possibility to implement the changes they might desire (Wolf, McQuitty, 2011; Dargahi *et al.*, 2020; Franke *et al.*, 2009).

It should be noted that DIY is mainly a self-expression of consumers of their role in the personalization of a product. They generally carry out their activities in an isolated way rather than within a community. However, Hienerth *et al.* (2014) showed that problem solving is more effective in an open community due to the involvement of different people with diverse skills and perspectives. The challenges and problems are solved faster and more creatively. Although DIY offers considerable possibilities for personalization, consumers need to be aware of their preferences (Tuli *et al.*, 2007) and to be able to identify their needs correctly when dealing with the problems (especially technical ones) that they may face during the creation of the object/product.

Finally, DIY practices develop in the form of workshops that take place in shared spaces with innovative equipment, tools, and methodologies. These shared spaces have turned isolated DIY practices involving solitary productive activities which took place at home (Gelber, 1997; Williams, 2004) into a more open and collaborative approach (Boutillier *et al.*, 2020; Morel *et al.*, 2018). These spaces take different forms: digital fabrication spaces (*e.g.*, fablabs, maker spaces, hacker spaces, tech shops) or collaborative reflection spaces (*e.g.*, living labs, coworking spaces) and they involve different communities with similar practices. DIYers in shared spaces, or users in other environments, collectively exchange their knowledge and know-how and benefit from the expertise and skills of experts, thus reinforcing their individual capacities and stimulating practical know-how. They engage in processes of co-creation and validation, and the prototyping and testing of new technologies or products in real-world contexts (Leminen *et al.*, 2012) by relying on the cooperative dynamics generated within a large community of prosumers. This evolution of DIY practices has generated a new dynamic of co-creation among users which is characterized by more organized operations, structured tools and methodologies. These open new perspectives of connection between users and their ecosystems, particularly in the manufacturing environment. The tools and methods of co-creation which characterize the way DIY operates in these spaces can induce a new, more open and participatory mode of manufacturing. It allows individuals to contribute to the different phases of the creation process, such as ideation, design in connection with manufacturers.

In our approach, the principle of DIT is based on the integration of DIY practices in the co-creation and customization phases of new products by companies. The objective of this process is to fully integrate the consumer as a prosumer and clearly detect their needs (*e.g.*, advice, expertise) by collecting information (*e.g.*, context, usage situation of the future product/service). Then, solutions to meet these needs are sought by involving a community of experts (Jiang *et al.*, 2016b) via physical spaces (for fabrication or reflection) or digital spaces (multiservice platforms, application). Like DIY spaces, digital spaces connect the community of experts to users to propose solutions to answer their needs and translate them into technical specifications to facilitate custom manufacturing and industrialization.

Hence, the co-creation part of DIT has similarities with known approaches such as design-thinking. It is a process commonly used by designers to find the solution to complex problems, navigate new or uncertain environments and create a new product. This process uses fundamental elements and skills of empathy, reflection, creation and experimentation to collaborate, create and build on results (Black *et al.*, 2019). Doorley *et al.* (2018) divided the design thinking process into 5 steps: (1) empathizing (understanding the problem), (2) defining (analyzing the information), (3) idealizing (generating ideas), (4) prototyping (experimenting ideas) and (5) testing. This approach fits well with our definition of DIT. Two other steps have been added to fully integrate a social fabrication approach: the modelling of solutions, which is part of a digitalization process, and validation, which makes the transition between the co-creation phase and the industrialization phase.

To summarize, co-creation can be divided into two sub-sections: co-design (Box 1), which includes understanding problems and generating ideas, and a "test through use" section, which includes modelling and prototyping, and is feasible in innovation spaces. Validation of product specifications leads to a production order. An overview of the DIT process, including the co-creation process, is presented in Figure 1.

**_Box 1_ – Difference between co-creation and co-design**

In the field of participatory design, the terms co-design and co-creation are nowadays often confused and used interchangeably. Co-creation is any act of collective creativity, *i.e.* creativity shared by two or more people (Wiegmann *et al.*, 2018; Sanders, Stappers, 2008). Co-creation is a very broad term with applications ranging from the physical to the metaphysical and from the material to the spiritual. By co-creation, we mean collective creativity as it applies to the entire design process. Thus, co-design is a specific example of co-creation. In some instances, co-design refers to the collective creativity of collaborating designers (Sanders, Stappers, 2008). We use co-design in a broader sense to refer to the ability of designers and non-expert people to work creatively together in the design development process.

### *An Open, Distributed and Decentralized Networked Manufacturing System*

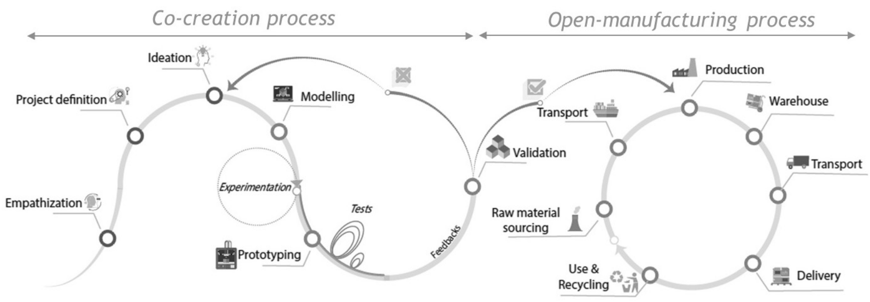
The DIT approach involves, on the one hand, consumers as prosumers and their ability to conduct a more widespread DIY method with relevant tools or spaces, and, on the other hand, a set of companies linked to the production of a product and/or creation of a service throughout its life cycle, such as the R&D, design, logistics, recycling phases, etc. DIT differs from traditional manufacturing modes because each manufacturer is connected to its community of consumers via centralized crowdsourcing (*e.g.*, social network platforms). According to Li *et al.* (2018, p. 308), the current so-called networked manufacturing system should evolve from an integrated and centralized system to an open and decentralized manufacturing system in which: "*Not only customers should be connected, but also enterprises should also be connected. Not only information should be shared, but also knowledge and services of enterprises on how to handle the information should be shared*". This is a new form of coordination of manufacturing systems, called open-manufacturing (Redlich, Bruhns, 2008). Characterized by the "Global Design, Local Manufacturing" model, open-manufacturing is a socio-economic production model, in which products are manufactured in an open, collaborative and distributed manner (Kostakis *et al.*, 2018). This model favors the global exchange of information flows on how to make the product (information, knowledge, design, codes, models, drawings, and so on, via digital platforms) rather than the global exchange of material flows. Local production limits material flows while facilitating the involvement of local users/

consumers in the manufacturing and production of the product. The user impacts the production of their product and their industrial system, since the user's choices will determine the involvement of companies in charge of product development. The industrial system is based on distributed exchange of knowledge and services (product customization, choice of materials…).

The manufacturing and industrialization of products designed during the co-creation phase of DIT relies on a network of interconnected companies involved in transformation and distribution activities (from raw material sourcing to product manufacturing and distribution to the final customer), known as a supply chain (Christopher, 2016). In a DIT approach, different stakeholders (users, companies…) are connected through cyber-physical-social spaces (Jiang *et al.*, 2016b) as well as physical spaces for co-creation. The manufacturing process supported by a supply chain must be open and mobilize technologies to coordinate all flows within the network (Redlich, Bruhns, 2008; Li *et al.*, 2018). Therefore, the "manufacturing" part of DIT is based on the different stages of a supply chain (sourcing, transport, production, storage, delivery and recycling) (Guide, Van Wassenhove, 2009; Soleimani *et al.*, 2017). It also mobilizes technologies that improve exchanges between the different stakeholders involved in the process (Jiang *et al.*, 2016a; Li *et al.*, 2018).

Based on these conceptual considerations, Figure 1, a synthetic representation of the DIT approach, focuses on the characteristic DIT processes: activities dedicated to creation (co-creation process) and activities dedicated to the production/supply of the personalized product (open-manufacturing process). A simplified view of the open-manufacturing part, only presenting the important function of manufacturing and supplying, is presented. Note that the DIT process is more complex with many interactions between the actors involved.

***Figure 1*** **– Simplified representation of the two main processes of DIT: the co-creation and the open-manufacturing processes**



To conclude, DIT is an alternative design process which allows for open global design and open-manufacturing, promoting local production closer to manufacturers/"prosumers" (Ritzer, Jurgenson, 2010). Indeed, it lets "prosumers" produce and consume goods which they have helped to design. Thus, they become active co-creators who could disrupt the existing local mass production industry. Co-creation of value brings benefits to all stakeholders involved in DIT processes by engaging a community of customers, professionals and producers from the co-creation of the product/service ideas to custom production.

Although our definition of DIT mobilizes concepts that are well known and documented in the literature, its organization on an industrial scale must be specified in order to advance research in this field. Clarifying the DIT process is also necessary to facilitate its operationalization by industrialists because DIT leads to changes in practice and the ways the different stakeholders work and exchange with each other.

## Design a Collaborative Production System Supported by a Digital Platform

The previous section defined DIT, allowing us to understand how stakeholders are involved in this updated manufacturing paradigm. However, the role played by the cyber-physical-social space within this new mode of manufacturing needs to be clarified in order to assess how it enables the decentralization of activities and the exchange of knowledge to produce more customized products. To support companies in their changes in practice, this section proposes an organizational framework combining aspects of the social manufacturing framework (Jiang *et al.*, 2016a) with those of an open-manufacturing framework (Li *et al.*, 2018). The objective of this organizational framework is to ease the management and capitalization of data generated at each stage of the DIT process and to grasp the nature of the exchanges (both of services and knowledge) between the different stakeholders.

### The Social Manufacturing Framework: Towards a Digital Manufacturing Paradigm

The logic framework of Social Manufacturing proposed by Jiang *et al.* (2016a), called "SocialM" by these authors, clarifies how companies and prosumers collaborate in production. It consists of four main steps: (i) self-organization, (ii) configuration, (iii) operation and collaboration, and then (iv) analysis and relationship management.

The self-organization step supports dispersed companies interacting with each other in a global network of social relations and which are organized autonomously into different communities of experts. The configuration step allows the prosumer to select different communities of experts, depending on their needs, to undertake tasks related to the product life cycle, thus forming a network. After configuration, the operation and collaboration steps lead to the product life cycle tasks being executed sequentially. Requirements are met through social interaction and information sharing/exchange within the network. In particular, during the manufacturing phase, real-time industrial data is collected. Then, analysis and relationship management allow the companies and prosumers to evaluate production, performance and company preference, based on the data collected.

The interactions between all these steps are coordinated in a cyber-physical-social network platform. Consumers, companies, suppliers and other stakeholders are a consumer-oriented community who exploit this platform as a collaborative production system.

Thus, the "SocialM" framework is divided into three aspects, supported by new information and computer technologies, as well as social platforms and tools:

- Self-organization of the networks of companies and configuration of communities of experts according to the needs of prosumers.
- Industry 4.0-based production control that allows interconnection using a cyber-physics system.
- Social interaction and collaboration between companies supported by communication tools within the cyber-physical-social platform that facilitates sharing between all stakeholders.

## The Open-Manufacturing Framework: Towards Knowledge Exchange

In an open-manufacturing context, the stakeholders seek to set up a knowledge exchange. Each company has its core knowledge, including knowledge of market and technology trends, of networks/supply chains, etc. Good knowledge of the company's expertise is a key factor to share, reuse and even exchange information within the ecosystem. The company must therefore communicate about its knowledge. For that reason, a support infrastructure is in charge of converting its information into a language shared by the stakeholders in the ecosystem and storing it. This knowledge must be adaptable to the situation of the stakeholder (economic, institutional or user actors). In addition, the manufacturing ecosystem provides fundamental technologies for knowledge while advanced computing provides fundamental facilities that support the network and storage of knowledge, leading to the exchange of services. As with knowledge exchange, an enterprise can share services over the network. Establishing an open-manufacturing ecosystem therefore requires setting up its physical infrastructure (the companies that make it up) and its digital implementation.

Li *et al.* (2018) propose a framework to encourage the exchange of knowledge between stakeholders in the future manufacturing ecosystem (Table 1). In our study, we state that DIT embodies individuals, companies and technological systems. The framework proposed by Li *et al.* (2018) identifies the knowledge exchanges carried out within this ecosystem from the cyber-physical-social system point of view. In this framework, the cyber-physical-social system is divided into several layers in order to understand: (i) how the information and data generated at each stage of the DIT process can be mobilized; and, (ii) to identify the resources (human and material) and/or companies that need to be mobilized.

***Table 1*** **– Representation of the exchanges between the different components of the DIT ecosystem from the cyber-physical-social system point of view (adapted from Li *et al.*, 2018)**

| **Layer** | **Purpose** | **Main components** | **Link with the other layers and the ecosystem** |
|---|---|---|---|
| **Customer layer** | Collect data from customers | Social networks, the Internet of Things, Internet applications, portals, mobile apps, customer surveys, etc. | Collected within co-creation spaces (fablabs, maker spaces, living lab, etc.) and analyzed by the company layer and the application layer |
| **Companies layer** | Collect data from different companies, allow the companies to share and access knowledge and resources | Manufacturers, suppliers, distributors, marketing companies, logistics companies, investors, data centers, data analysts, etc. | Use and analyze data from the customer layer<br>Work through the application layer<br>Generate and provide different kinds of knowledge, resources, and services for the ecosystem |

| **Layer** | **Purpose** | **Main components** | **Link with the other layers and the ecosystem** |
|---|---|---|---|
| **Application layer** | Provide applications for companies and allow companies to share their applications | Systems of companies such as CRMS, SCMS, LMS, DMS, DSS, MES, ERP, CAD, etc. | Work closely with the intelligence layer and data layer |
| **Intelligence layer** | Carry out analytical and reasoning processes | Different artificial intelligence tools, statistical methods and computational technologies such as machine learning, planning, inference, searching, data mining, optimization, natural language processing, etc. | Provide the processing power for the application layer to carry out analytical and reasoning processes |
| **Data layer** | Store the data and information collected, shared and generated from the different layers | Different databases and knowledge repositories | Provide memory for the application layer<br>Store the data from the customer layer and the application layer<br>Analyze and process results from the company layer and the application layer |
| **Infrastructure layer** | Provide the infrastructure to support the different layers | Block chain and Edge computing | Support the establishment of the entire framework by providing the hardware infrastructure for the ecosystem |

In the context of DIT, knowledge exchange is an essential feature to satisfy the customer. This knowledge can be: (i) basic knowledge, such as market and technology trends, networks, experts, customers, supply chains; (ii) organizational knowledge, on supporting infrastructures, structured processes and databases of the organization; or, (iii) technical knowledge, such as technological characteristics, manufacturing constraints, raw materials (Li *et al.*, 2018). Knowledge sharing aims to ease exchanges within the ecosystem through the cyber-physical-social system (referred to in the framework as the infrastructure layer, including for example, blockchain, edge computing). The purpose of this system is to collect data from companies to implement DIT. Based on the information at its disposal (customer or company information), it must connect the various stakeholders to achieve the expected product. Hence, this system makes this knowledge available to all stakeholders, leading to the exchange of services (complementary to the product) such as the provision of expert communities, support in the search for a solution (*e.g.*, advice, material resources), product development and manufacture, assistance, information and data exchange, or networking among others.

In concrete terms, the DIT approach engages users in a co-creation process through innovation spaces or adapted digital technologies. These tools (physical and/or digital) are intended to provide them with workflows and simple tools to generate new products. The results of co-creation activities are collected, analyzed and represented in a specifically developed cyber-physical-social system. The latter contains features that facilitate exchange, creativity, ideation and design for example. It is then a question of helping users acquire skills that they do not master and giving them access to specific technologies (*e.g.*, immersive technologies, virtual reality, computer-aided design). Outputs of the co-creation platform are designs that must be made available to the manufacturers. The cyber-physical-social system must simplify the translation of the designs into files exploitable by manufacturers. For that reason, manufacturers must transmit information about their activities to the platform to allow the networking of several production means in charge of manufacturing the product. Then, the cyber-physical-social system integrates a management software such as Enterprise Resources Planning to connect the different companies and improve production management.

## Organizational Framework of Do-It-Together

The DIT approach integrates a creative process and a service-oriented manufacturing process (open-manufacturing), encouraging different economic actors (the companies of manufacturers, distributors, designers, etc.) to organize themselves into a community of experts. Its implementation is supported by a shared digital space, promoting knowledge and information sharing between the different stakeholders (users, companies, communities), collaboration (creative and commercial), exchanges of services and global production management to accomplish the tasks in the product life cycle. Its functioning then requires a set of data from users (problems, identified needs, ideas and requirements) as well as data from enterprises. This includes strategic data (*e.g.*, products and services, business models), organizational data (*e.g.*, partners, supply chains), and operational data (*e.g.*, technology, production capacity, raw materials). The DIT organization can be achieved by combining and adapting the "SocialM" logical framework concept of Jiang *et al.* (2016a), and by clarifying the digital aspect using the framework of Li *et al.* (2018). As a result, the DIT approach is organized as follows.

Analysis and management occur through the digital space. It collects data from users and companies and mobilizes the different layers (applications, intelligence, data) of its architecture to provide the expected results. The digital space is divided into two main activities: configuration/customization and production management.

Configuration is both creative (through product creation) and manufacturing:

1. Product configuration depends on the results obtained during the co-creation process. A product concept is selected according to the requirements of use, customization and environmental constraints issued by the future users as well as industrial feasibility. This product concept is then transformed into specifications.

2. Industrial configuration is based on user requirements; companies are selected according to their capacities, means, know-how, practices and location and then networked to configure the product/service production process.

Production includes both creation (through the co-creation process) and manufacturing (though the open-manufacturing process).

3. The co-creation process provides the user with support to identify their problem, to achieve their idea or to customize an existing product concept. Users can interact and share information with expert communities (designers, manufacturers…). Data is collected and capitalized on in the digital space to be disseminated to companies.

4. After industrial configuration, the processes which lead to the manufacturing of the product are executed sequentially. User needs are met through interaction and information sharing. Data is collected in real time to be disseminated to the user.

The interactions between each section are coordinated via the digital space in which all the stakeholders form a user-oriented community can exploit it as a collaborative production system. This digital space is based on different interconnected layers supporting its services:

- A customer layer which collects their data: problems, ideas, needs, environmental constraints, technical constraints, desire for customization, usage requirements, etc.;

- A company layer that collects data from different companies: production requirements, technology, production capacity, design and production knowledge (industrial feasibility), materials, means of production, environmental practice, etc. It also allows knowledge sharing and access to resources.

- An application layer that facilitates the collection and sharing of customer and company data.
- An intelligence layer that carries out analytical and reasoning processes.
- A data layer that stores all the data used within the digital space.
- An infrastructure layer that will support all these layers.

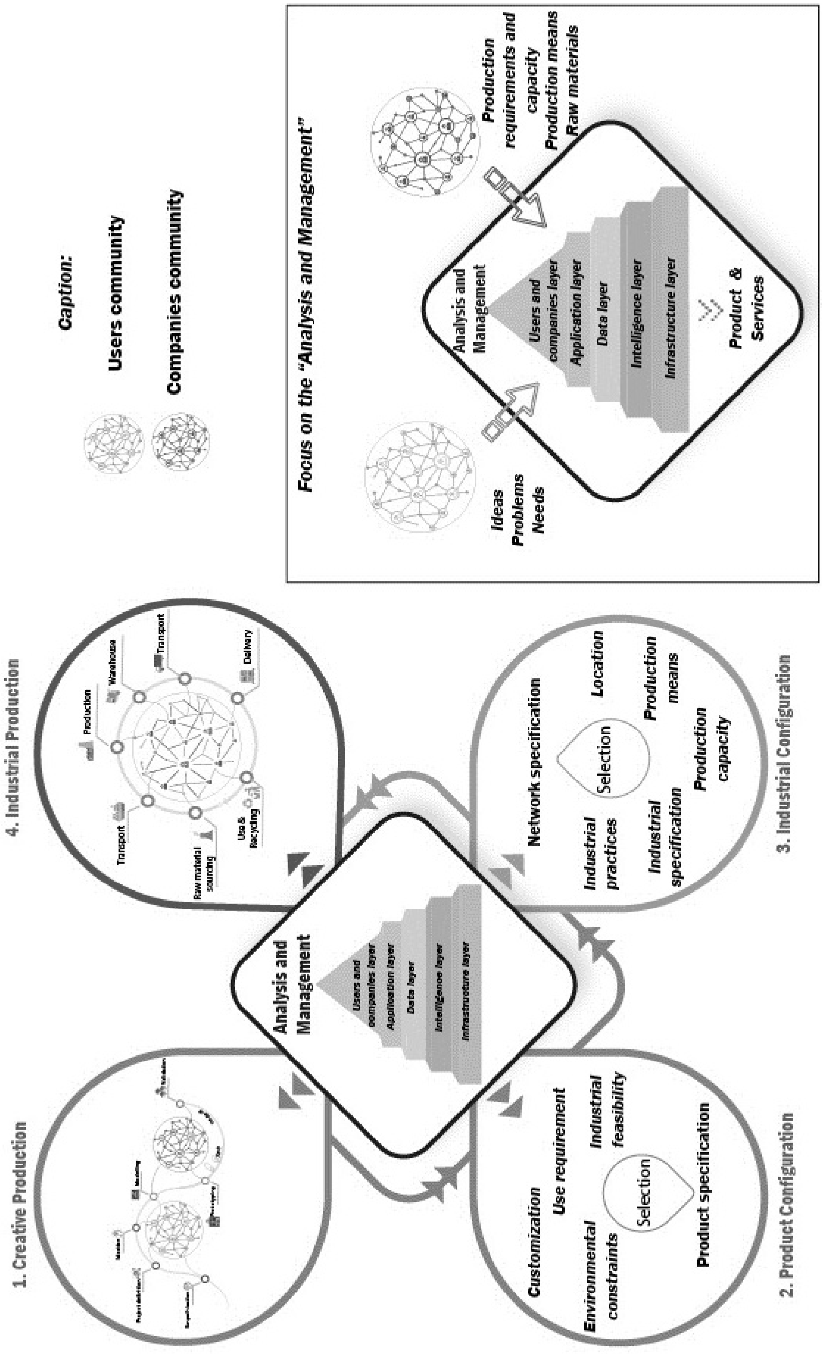
The digital space will collect data, analyze it, and adapt it in order to apply and distribute it to the different sections (creative production, product configuration, industrial configuration, industrial production). It participates in the effective progress of the DIT approach.

Figure 2 shows our proposed organizational framework for DIT, including analysis, management, configuration and production. The diagram is read counter clockwise so that the production part (including 1-creative production and 4-industrial production) are on top. The configuration part of the framework (including 2-product configuration and 3-industrial configuration), which serves as the basis of production, is at the bottom.

## A Paradigm Shift to Strengthen DIT for Its Application

The link between industry and digital technology is the focus of a growing number of studies. New concepts have emerged in recent years to apply the principles and technologies of the Internet of Things (IoT) to the manufacturing industry. Industry 4.0, also known as Industrial Internet, is one of these new concepts. It is not a single technology, but a sociotechnical concept in which technological aspects (*e.g.*, automation, large data), social aspects (*e.g.*, communities, communication, human-computer interaction, collaboration) and organizational aspects (*e.g.*, decentralization, flexibility, interconnectivity, personalization, efficiency, IoT, cyber-physical systems, integration, autonomy, service orientation and data management) interact (Beier *et al.*, 2020). This original approach aims to build the theoretical and operational bases to facilitate a smooth transition towards the new industrial revolution. However, the concept of Industrial Internet is criticized by both academics and companies for its lack of clarity which makes its implementation difficult (Hermann *et al.*, 2016; Wan *et al.*, 2015).

*Figure 2* – Organizational Framework of Do-It-Together



By linking industrial production systems to the virtual world and integrating people into manufacturing processes, the DIT approach is part of Industry 4.0. DIT is based on new industrial, economic and organizational strategies, favoring a logic of mass customization and cyber-connection between the different actors. It brings novel values (economic, environmental, social values and in terms of knowledge) not only for manufacturers, but also for consumers/individuals and all the actors involved. The particularity of the new DIT approach lies in the transposition and adaptation of DIY principles to consumers and the potential mobilization of communities of makers. The latter are characterized by an agile organization around communities of interest, distributed production and open-source tools linked with digital technologies.

However, the implementation of DIT requires a significant paradigm shift from a scientific, technological, commercial and organizational point of view. It must be progressive and its technological and industrial feasibility must be demonstrated. This dimension is not addressed in this work which aims to establish a conceptual basis to define and clarify the processes to implement this new approach. The term demonstrator is commonly used, if the model and the simulations carried out with it are used to visualize functionalities and modes of operation. The demonstrator is a way of providing a central reference to help users interact with the simulated system, but also with each other (Moultrie, 2015).

Because of its industrial aspect, research into industrial demonstrators seems relevant. Like a product, an industry evolves according to technological developments, innovations, and social or political changes, among others. In the literature, different frameworks have focused on the industry life cycle (Phaal *et al.*, 2011; Tikkanen, 2008; Ansoff *et al.*, 2018). Based on the STAM model (Science-Technology-Application-Market), the representation proposed by Phaal *et al.* (2011) is interesting because it focuses on the early stages of industrial evolution. These are particularly associated with the emergence of the "embryonic" phase. This phase validates scientific concepts into technological prototypes and demonstrators before the first application. Transitions among several phases (science-technology, technology-application and application-market) facilitate changes in management and the identification of specific milestones (demonstrators) that delineate the different phases.

Thus, the demonstration of a DIT approach requires, among other things, validation of the feasibility of the cyber-physical system, the services provided by these new technologies, the new industrial organization, the customization process, and data management. Based on the work of Phaal *et al.* (2011)

and Moultrie (2015) and our research on DIT, some demonstration possibilities can already be considered:

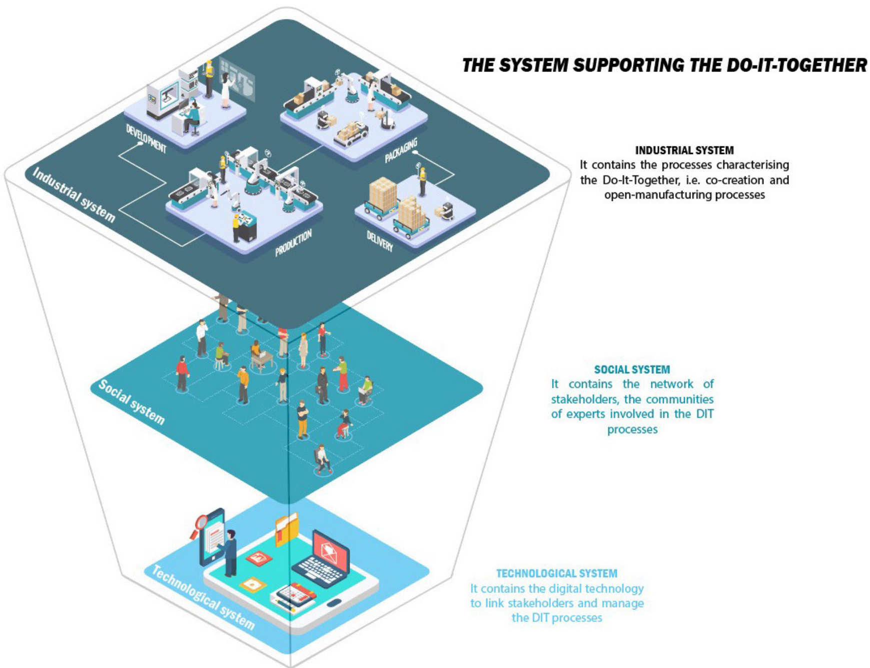
- From a scientific point of view: new fundamental knowledge concerning industrial equipment or exchange systems between stakeholders, feasibility of the practical potential of industrial equipment or exchange systems between stakeholders in a market-oriented field of application, etc.
- From a technological point of view: development of industrial prototypes (machines, platforms…), capacity of the industrial system to scale-up production.
- From an application point of view: functioning of the industrial equipment or exchange systems in real conditions, ability to meet mass demand while being flexible, etc.
- From a commercial point of view: ability to meet market demand and customization, ability to be competitive in the market, identification of market opportunities.

However, the proposed definition of DIT emphasizes that the demonstration cannot be limited to an industrial one. Indeed, it is characterized by:

- An industrial dimension represented by a co-creation process and an open-manufacturing process;
- A social dimension through the involvement of users and social interactions within the co-creation and open-manufacturing processes;
- A technological dimension through a cyber-physical-social space supporting social interaction and the implementation of the DIT approach.

The implementation and deployment of the DIT approach is based on a broad system, integrating interconnected companies and facilities. This system mobilizes individuals, facilities, companies and technologies that will organize themselves to meet the personalized needs of end users. Indeed, the specificity of DIT lies in the fact that it involves different stakeholders, including users in the design and production process through technology (platforms, digital tools, etc.) (Mohajeri *et al.*, 2014; Jiang *et al.*, 2016c). From this perspective, we consider that the system that supports DIT is a combination of three systems: a social system, an industrial system for open-manufacturing, and a technological system, the latter supporting the others (Figure 3).

*Figure 3* – **The system supporting the DIT approach**




The demonstration of such an approach will depend on the organizations involved, and the maturity of the technologies mobilized (TRL-type). The joint demonstration of three systems, as presented in the DIT approach, is not addressed in the scientific literature. However, certain works present avenues of demonstrations for the DIT technological system. In their article, Oks *et al.* (2019) propose a reference architecture for a cyber-physical-social system. This representation makes it possible to describe the content of such a system (software, hardware). However, it fails to address the way in which all the stakeholders interact. At the stage of our research, this type of architecture is necessary but not sufficient to fully understand and demonstrate a DIT approach. Therefore, this demonstration requires the design of engineering capable of jointly developing digital and manufacturing technologies and networks (manufacturing and social).

Our contribution is a first step in the deployment of the DIT approach. Our ongoing works focus on the demonstration and the validation of the feasibility of our definition and organizational framework as well as on the services provided by the actors involved in this approach (in particular by companies and users through cyberspace). The aspects of socialization, personalization, and mass collaboration of DIT will be an important part of our future research. Particular attention may be paid to the notion of servitization. Indeed, the DIT approach is an opportunity for the companies involved to begin a transition towards servitization, *i.e.* to engage in a transformation process from a product-centered logic to a service-centered one (Kowalkowski *et al.*, 2017). It means that companies no longer limit themselves to selling products, but offer packages of customer-oriented combinations of goods, services, support and knowledge to provide additional use value (Paschou *et al.*, 2020). Through its cyber-physical-social space, the DIT approach facilitates and promotes the exchange of services (co-creation of the product, manufacture of a customized product, mobilization of a network of companies...) and associated knowledge, in addition to the product itself.

## Conclusion

The objective of this article was to give a definition of the DIT approach in order to promote it and deploy it at an industrial scale. DIT stems from the logic of social manufacturing, which consists in proposing new manufacturing methods to meet the increasing demands of customization. Social manufacturing mobilizes a few key elements: (1) the concept of prosumer, (2) a cyber-physical-social space, (3) social interaction, (4) prosumer relationship, (5) community and (6) social context (Jiang *et al.*, 2016b). Moreover, the DIY approach is widely disseminated in the socio-economic environment and many actors have seized this movement. The DIY concept is currently well-known and studied in research. Use cases and studies on the subject are an opportunity for cross-fertilization between customization practices and manufacturing processes.

The contributions of our study are both theoretical and empirical. On the theoretical level, this study makes it possible to clarify the DIT concept. Indeed, this notion has only recently emerged thanks to the development of Industry 4.0 technologies and its definition is still in progress. Thus, based on the literature of the concepts of social manufacturing and DIY, a definition of DIT was proposed. DIT is a social manufacturing approach based on the co-creation and open-manufacturing of customized products involving consumers assisted by a community of professionals and experts. DIT is carried out more closely with the user and the final consumer which brings new values and innovation dynamics. DIT is defined as an alternative design process that allows for open design and manufacturing. From this definition, a generic DIT process and an organizational framework were proposed. The definition of DIT is based on knowledge in the fields of co-creation and open-manufacturing. The organizational framework is a combination of the social manufacturing model of Jiang *et al.* (2016a) and the open-manufacturing model from Li *et al.* (2018). The former clarifies how stakeholders collaborate to design customized products while the latter describes how the exchange of services and knowledge between stakeholders is organized.

Implementing the DIT approach in practice now requires the development of an empirical application to validate the different demonstration aspects. In this perspective, our future work will focus on the study of the implementation conditions of the DIT approach Demonstrator. Indeed, specific ecosystems, logistics and business models need to be designed and implemented to disseminate it in the private sector. This Demonstrator will contain several demonstration facilities (called OMFD for Open Manufacturing Demonstration Facilities) located in five European countries, namely Spain, Portugal, Switzerland, Italy and France. Each facility demonstration will verify and validate one or several steps/phases of the DIT approach to consider the scientific, technological, and commercial aspects and applications. All these demonstration facilities will be coordinated by a digital platform whose creating conditions are currently being studied.

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