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# D2.6 iPRODUCE Social Manufacturing Vision and Reference Model

CERTH

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| 29/10/2020 | V0.1 | CERTH | First version with all elements included |
| 6/10/2020 | V0.2 | CERTH, CBS | Updates based on peer review process and quality check |
| 12/11/2020 | V0.3 | CERTH | Final draft reviewed |
| 13/11/2020 | V0.4 | CERTH | Final version submitted to the European Commission |

| DISSEMINATION LEVEL | | |
|---|---|---|
| PU | Public | X |
| PP | Restricted to other programme participants (including the EC services) | |
| RE | Restricted to a group specified by the consortium (including the EC services) | |
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iPRODUCE ● Grant Agreement: 870037 ● Innovation Action ● 2020 – 2022 | Duration: 36 months

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# List of Abbreviations & Definitions

| Abbreviation | Definition |
|---|---|
| API | Application Programming Interface |
| AR / VR | Augmented Reality / Virtual Reality |
| B2B | Business to Business |
| B2C | Business to Consumer |
| cMDFs | collaborative Manufacturing Demonstration Facilities |
| CNC | Computer Numerical Control |
| Component Diagram | A component diagram describes the organization and wiring of the physical components in a system |
| Conceptual architecture | Conceptual architecture is a form of architecture that utilizes conceptualism, characterized by and introduction of ideas or concepts from outside often as a means of expanding the discipline of architecture |
| DIH | Digital Innovation Hub |
| EC | European Commision |
| IPR | Intellectual Property Rights |
| ML | Machine Learning |
| MSB | Makerspace Bonn |
| OpIS | Open Innovation Space |
| SME | Small and medium – sized enterprises |
| SMF | Social Manufacturing Framework |
| UC | Use Case |

# Executive Summary

The deliverable D2.6 "iPRODUCE Social Manufacturing Vision and Reference Model I" by month 9, focuses on strengthen iPRODUCE vision on how social manufacturing framework can work in the consumer goods sectors.

In particular, the D2.6 regards the fusion and synthesis of the outputs from T2.1-T2.4 in the form of a position paper and:

- provides the proposed social manufacturing framework, the identified stakeholders, their main needs and the drivers for their participation to social manufacturing, the business, operational, and technical challenges that they face as well as which existed methods, functions, services & tools they use under co-creation activities.
- includes the structure that local cMDFs and ecosystems can adopt, the scope of their federation, the governance principles they can apply as well as the intellectual property management, data management and ethics, occupational health and safety issues that have to consider.
- presents the reference models for digital manufacturing platforms and the iPRODUCE reference architecture model approach.
- presents the iPRODUCE platform main components description and the high functional view of their architecture. Also, in this section is described how these robust digital components will address the business, operational and technical challenges that appeared within a social manufacturing framework.

The D2.6 is the first version of the documentation of the Social Manufacturing Reference Model and Framework Evolution. This document will be enriched by the second version on month 18 by D2.7 "iPRODUCE Social Manufacturing Vision and Reference Model II" and the last version on month 36 by D2.8 "iPRODUCE Social Manufacturing Vision and Reference Model III".

The D2.6 is a public document (PU) and is, therefore, intended for the European Commission, the iPRODUCE Project Officer, the members of the iPRODUCE consortium, the members of other national and H2020-funded projects, as well as, the research and industry more widely, and even the general public.

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# 1. Introduction

iPRODUCE delivers a novel social manufacturing platform that enables multi-stakeholder interactions and collaborations to support user-driven open-innovation and co-creation. This platform is an open digital innovation space (OpIS) that facilitates cocreation ventures through secure and interoperable exchange of data and domain-specific intelligence. The OpIS is utilised by a set of innovative digital tools that support matchmaking, secure interactions, generative product design, process orchestration, co-creation up to agile prototyping, usability evaluations and lifecycle management. The iPRODUCE platform is deployed in local 'ecosystems' (composed of SME association, manufacturing and specialist SMEs, Fablabs, Makers spaces etc) under the notion of collaborative manufacturing demonstration facilities (cMDFs). The platform supports knowledge and resource sharing across cMDFs through which a federation of cMDFs is established. The cMDFs and the iPRODUCE platform are equipped with novel co-creation methodologies, training toolkits and sharing-economy business models to adapt the organisational systems, shape the social manufacturing processes and scale collaborative production activities.

The purpose and scope of this deliverable 2.6 (henceforth referred to as D2.6) is to elaborate and integrate the results provided by Deliverables D2.1, D2.3, D2.4 and from Task 2.4 "Defining the Local Collaborative MDFs, Use-Cases, Innovation Challenges and KPIs" into a holistic visionary social manufacturing/ collaborative production reference model and further update/ improved throughout the project duration.

The holistic vision of the reference model related to the iPRODUCE architecture and open innovation approach is presented here within the D2.6 "iPRODUCE Social Manufacturing Vision and Reference Model I" on month 9, as a first version and will be updated in subsequent versions on D2.7 on month 18 and on D2.8 on month 36.

This first version in the form of a position paper provides:

- An overview of the proposed social manufacturing framework
- A description of the role of each the involved stakeholders and how they may interact to create and share value on a positive sum context
- A prioritisation of the main needs that the framework should address and a description of the corresponding necessary methods, functions, services and tools
- The identified business, operational, technical challenges and how they can be addressed by the iPRODUCE platform through the robust digital tools that integrates
- A description of the proposed structure that local cMDFs and ecosystems employ, the governance principles they can apply and horizontal issues including regulations, intellectual property management, data management and ethics, occupational health & safety issues.
- The scope of the federation of local cMDFs
- A presentation of iPRODUCE's SMF main elements (digital toolkits), architecture and open innovation approach.

# 2. Social Manufacturing Framework Overview

## 2.1. Social Manufacturing Framework

Social manufacturing is associated with the maker and Do-It-Yourself (DIY) movement. Social manufacturing is characterized by the systematic utilization of the power of communities to design and manufacture high personalized goods and is strongly associated with point of need manufacturing, and production via additive manufacturing technologies[1]. As a phenomenon it is well-established in most developed countries and involves substantial levels of consumer awareness, interest, and activity. The short-term and long-term development expectations of social manufacturing by 2030 are shown in Figure 1.

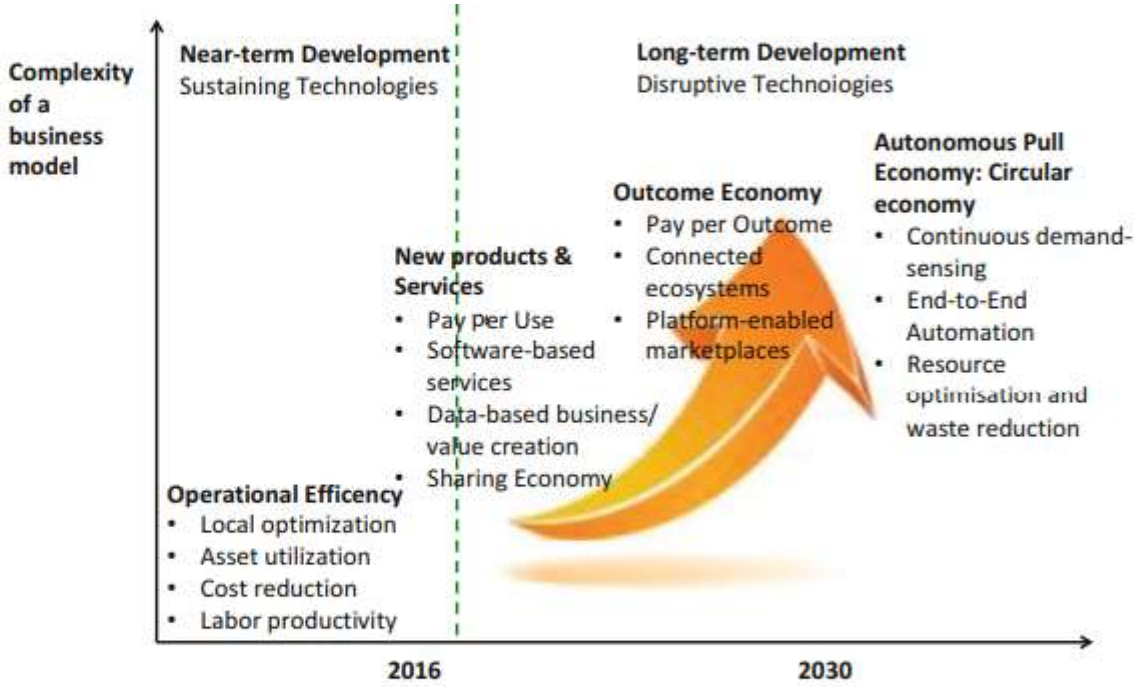


Figure 1: Short-term and long-term development expectations of social manufacturing framework[1].

In order to enhance makers' communities to collaborate with other identified stakeholders under co-creation and sharing economy, the European Commission (EC) invites policy makers to support social manufacturing by encouraging shared physical and digital manufacturing infrastructure and networks. Also, the EC further calls for regulation that encourages and mainstreams democratised manufacturing.

Based on this direction the iPRODUCE project introduces a novel Social Manufacturing Framework (SMF) that embraces manufacturing companies in the consumer goods sector, their associations/networks, Fablabs/makers spaces, "Do-it- Yourself" (DIY) communities and various other innovation players at a local level. iPRODUCE SMF propels all the aforementioned players to validation in mass-production environments, in economies of scale and in dealing with a wide variety of products. The iPRODUCE conceptual architecture is illustrated on Figure 2 as described within the DoA.

[1] © Springer Nature Switzerland AG 2019
W. Leal et al.(eds.), Responsible Consumption and Production, Encyclopedia of the UN Sustainable Development Goals, https://doi.org/10.1007/978-3-319-71062-4_9-1

The iPRODUCE SMF delivers a novel social manufacturing platform that enables multi-stakeholder interactions and collaborations to support user-driven open-innovation and co-creation based on DIY manufacturing, while allowing the addressing of intellectual property protection issues.

To do so, it employs popular and well-proven Fab-Lab concepts and makers approaches and installs them in well-connected local collaborative multi-stakeholder ecosystems that are transformed to Collaborative Manufacturing Demonstration Facilities (cMDFs).

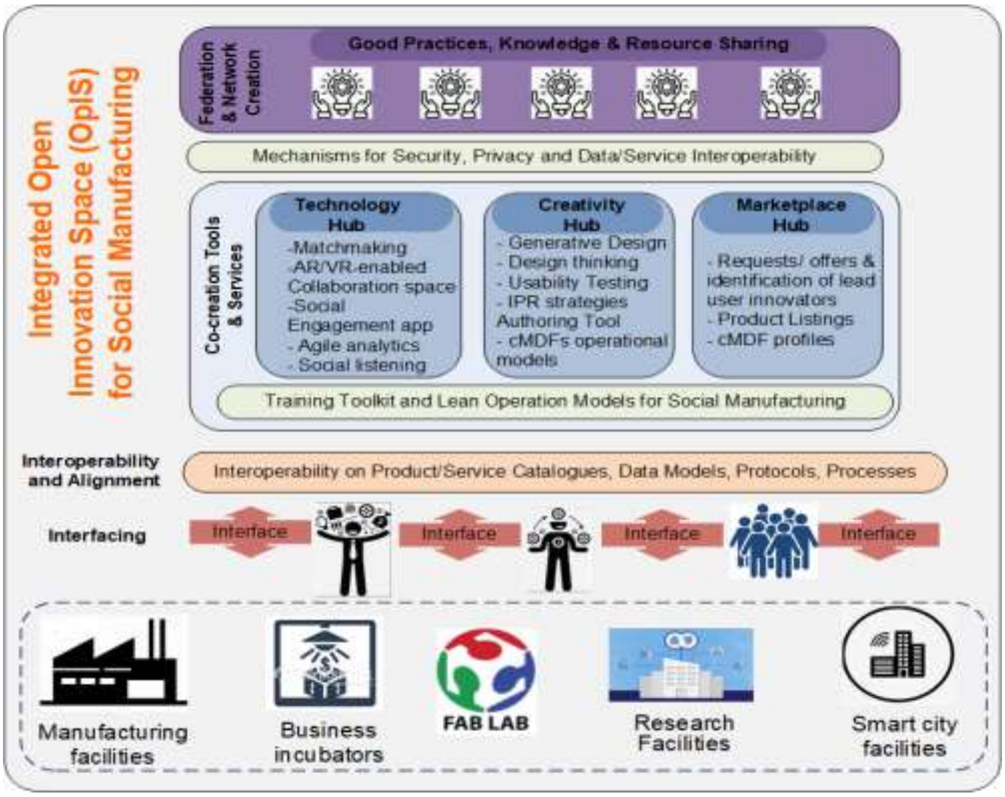


Figure 2: iPRODUCE Conceptual Architecture Overview as described DoA.

Local cMDFs comprise the locally dispersed physical spaces and production facilities. Under iPRODUCE framework, local cMDFs are getting interconnected in a loose and flexible federated organizational structure that enables knowledge extraction and sharing, as well as sharing of resources and of manufacturing facilities to community.

The project uses the current state-of-the-art social engagement practices, relevant ICTs and manufacturing technologies, synchronize them in order to function altogether under a digital Open Innovation Space (OpIS) for personalised products and fast prototyping. The iPRODUCE platform, OpIS, is the first digital platform which attempts to establish a collaboration between makers and the industry / manufacturing stakeholders, factoring in confidentiality as an important pillar. Thus, iPRODUCE gives the opportunity to makers to deal with a long-range of products, large-scale production and a bigger customer base.

In order to achieve that, the project employs novel open innovation methods, innovative digital tools, social engagement strategies involving attention economics, services, lifecycle procedures and facilities (i.e. cMDFs) with digital modelling and fabrication capabilities. In addition, the project promotes the use of micro – manufacturing equipment for personalised products and fast prototyping.

## 2.2. Stakeholders under Social Manufacturing

Social manufacturing happens at the premise of shared participation between established firms and independently operating individuals in the production of physical goods.

The iPRODUCE identified the key stakeholders of social manufacturing framework. These are:

a) Manufacturing enterprises (mainly SMEs and/or mid-caps)

b) Makers communities (including DIY, Fablab, makers spaces and startup communities)

c) Prosumers (is a proactive consumer that participates in social manufacturing, namely, a dual-role as both producer and consumer)

d) Consumers/Buyers

e) Competence Centers, Digital Innovation Hubs, Test beds and Manufacturing Demonstration Facilities, Research/Technological Centers and Institutes

iPRODUCE group the identified key stakeholder categories mentioned above into three main groups:

**Makers (Maker/Producer):** people who share a common passion around handcrafts, craftsmanship. grassroot innovations, and DIY projects as b) makers communities and c) prosumers. Makers are a large group that can consist of a range of interests: from hobbyists to traditional artisans to more advanced software developers, and could include craftsmen, designers, artists, musicians, cooks, students, welders, scientists, engineers and software developers.

**Consumers:** Buyers and customers as a) Manufacturing enterprises or individuals who will ask for training services, rapid prototypes and micro-manufacturing services e.g. 3D printing etc and future users of the OpIS..

**Collaborative Manufacturing Demonstration Facilities (cMDF):** Local / regional ecosystem that has the base infrastructure to support collaborative production and the facilities for user engagement, co-creation, validation and training. This category includes stakeholders as a, b and e.

The makers are the heart of the social manufacturing. Although they may cooperate with companies in their use of these distributed technologies, makers' attitudes toward and uses of these resources vary significantly from what is typical of manufacturing companies. Instead of focusing on profit, many makers take on projects primarily to boost their own learning, to cover at least some of the costs they incurred as hobbyists, or for other personal reasons[2]. If companies are able to acknowledge and support these goals, they can expect to attract enthusiastic and committed co-creators who may in some cases develop into longer-term partners in cooperative firm-individual social manufacturing.

## 2.3. Stakeholders Main needs – Drivers for Social Manufacturing Participation

One of the core tasks in iPRODUCE under the social manufacturing framework is the establishment of the OpiS (iPRODUCE digital platform) that will connect makers, manufacturing SMEs, and consumers. Aiming to develop OpIS that would better respond to the preferences of the project's stakeholders, a survey conducted and reported in the D2.1, seized the opportunity to identify the main needs of the

[2] M. Hamalainen, et al., Social manufacturing: When the maker movement meets interfirm production networks, Business Horizons, Volume 60, Issue 6, November–December 2017, Pages 795-805

stakeholders under social manufacturing. The study was targeted to consumers and makers and stakeholders from the manufacturing SMEs/Industry. Survey participants were specifically asked to prioritize their needs by indicating how essential a series of suggested features would be in a digital platform for social manufacturing (see Table 1).

Table 1: Features considered to be extremely crucial in a Digital Platform for Social Manufacturing.

| | Not important at all | Of little importance | Of average importance | Very important | Extremely crucial | Very important + Extremely crucial |
|---|---|---|---|---|---|---|
| List of makerspaces/Fablabs' manufacturing equipment | 0.58% | 2.09% | 14.27% | 40.72% | 42.34% | 83.06% |
| Training activities | 0.35% | 3.02% | 14.04% | 41.30% | 41.30% | 82.60% |
| Easy-to-use digital tools | 1.74% | 3.60% | 16.36% | 40.26% | 38.05% | 78.31% |
| Collaboration tools (e.g. tools enabling remote collaboration) | 1.74% | 2.44% | 18.10% | 42.11% | 35.61% | 77.72% |
| Technical lectures and mentoring from qualified experts | 1.04% | 2.90% | 17.87% | 43.85% | 34.34% | 78.19% |
| Pool of experts' profiles | 1.16% | 2.44% | 18.33% | 47.33% | 30.74% | 78.07% |
| Matchmaking services between SMEs and makers | 1.51% | 4.06% | 25.87% | 43.39% | 25.17% | 68.56% |
| Social network tools (e.g. discussion Fora) | 2.32% | 8.35% | 26.33% | 40.14% | 22.85% | 62.99% |
| Inspection and metrology tools for quality control | 1.16% | 5.57% | 28.89% | 42.46% | 21.93% | 64.39% |

Within D2.1 survey, were also identified the drivers that could potentially incentivize the above stakeholders' participation in social manufacturing spaces.

The participants' overall positive perspective was their willingness to join a makerspace/Fablab with a 65.20%. The vast majority of the total population sample is willing to be involved in social manufacturing activities 67.06% and join a social manufacturing workshop 67.99%, mostly aiming to gain access to training, digital tools, exchange ideas and to participate in workshops and projects for digital modelling and fabrication using a digital platform 74.47%.The study found that among the three targeted stakeholder groups, makers appeared to be more enthusiastic about joining a makerspace (Consumers: 20%, Makers: 62%, Manufacturing SME/industry: 28%) .

In the case of consumers and makers audiences, it appears that the main reason of participation in social manufacturing are: (i) meeting people with common interests by 46.56%, (ii) acquiring new technical skills by 87.94%, (iii) exchanging knowledge by 87.63% and (iv) extending network consist important drivers towards participating in a social manufacturing project by 87.02%. Interestingly, the prospects of earning money or peer recognition are not popular among the proposed potential drivers in this sample. A 20% share disagrees or strongly disagrees with being involved in the maker movement to gain financial rewards.

In the case of the manufacturing SMEs respondents, it appears that the main reason of participation in social manufacturing are: (i) testing new product designs and evaluating products before reaching the market by 80.19%, (ii) developing products that better reflect personal needs by 82.13%, (iii) identifying new commercial opportunities by 77.78% and (iv) better sharing visions with customers consist essential drivers towards participating in a social manufacturing project by 74.88%. The prospects of reducing the cost of developing products and services or becoming more self-aware on sustainability issues did not constitute popular drivers among this group.

The D2.3 survey has also identified the types of activities that participants would wish to implement through their potential participation in social manufacturing spaces (Fig.3) and their main targeted sectors (Fig.4).

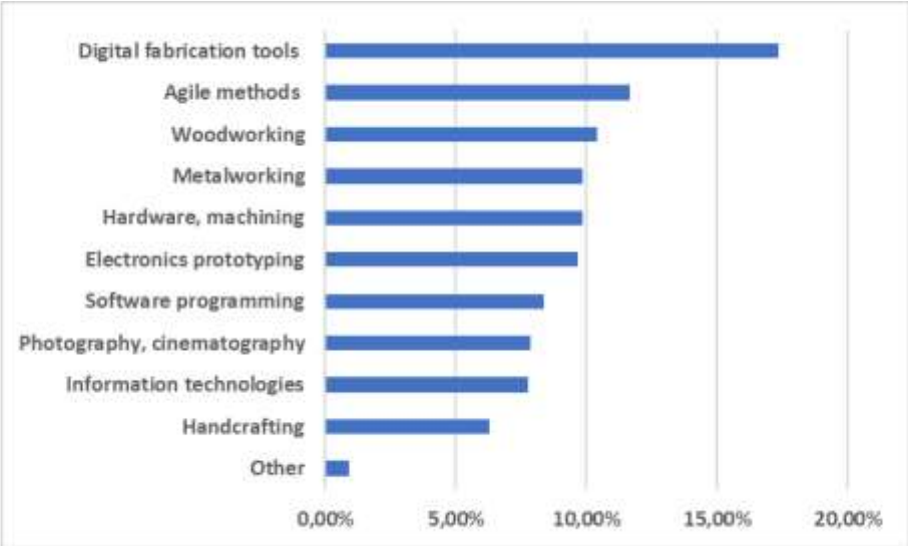


Figure 3: Types of activities that stakeholders are willing to implement through their potential participation in SMF.

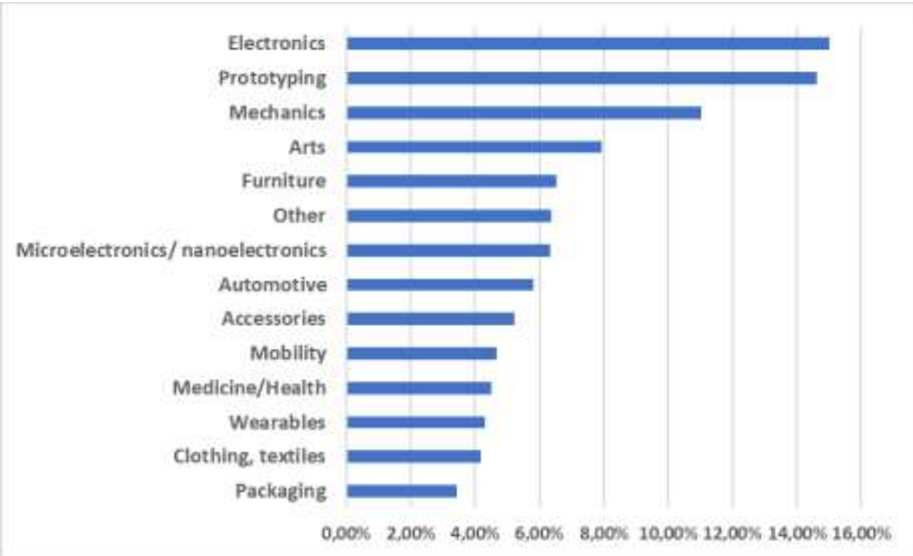


Figure 4: Stakeholders main targeted sectors in SMF.

## 2.4. Existing Methods, Functions, Services & Tools used by Stakeholders

iPRODUCE performed within D2.4 a study to map and assess existing platforms and tools with a strong application in Design Thinking and co-creation/co-production projects and approaches. The results indicate that over 100 co-creation and co-production tools and resources as well as communication platforms are used across projects for various purposes identified thorough literature review and desk research. The identified methods and tools cover all aspects of co-creation project phases: team building, research, ideation, development, assessment and evaluation and validation.

The mapping and assessment of co-creation/co-production methods and tools were divided into 3 sets:

- Online resources - covering online sites and platforms.

*The most relevant identified platforms with iPRODUCE SMF are: Thingverse[3], Arduino[4], Ada Fruit[5], Sparkfun[6], Hackday[7], Quirky[8], Trinkcle[9]*

- Co-creation/co-production resources – covering various activities, models and services.

*The most relevant identified platforms with iPRODUCE SMF which are the most popular in use* among the iPRODUCE partners and external respondents *are: Low-fidelity prototyping[10], Sketching[11], Storyboards[12], Hackathon[13], Business Model Canvas[14]*

- Communication resources – communication platforms and services.

*The most popular in use* among the iPRODUCE partners and external respondents *are:* Skype & Skype for Business, Slack, Meetup, Zoom, GotoMetting

The most popular identified methods and tools are frequently used for various projects and they relate to both software required for interacting with hardware production, involving modelling, data analysis, product simulation, testing, etc. Many of the methods and tools are used across projects and in different phases aided of hardware equipment and materials, such as microcontrollers, sensors, gears, etc. Furthermore, these tools are used also towards physical prototypes and final products, as well as towards analysing and testing the products.

Even though the aforementioned co-creation/co-production methods and tools indicate the most popular tools and resources, thus indicating the most used and applied tools, the project partners should engage in the opportunity to explore the knowledge base herein presented as a way to expand their toolboxes, creating new standards for social manufacturing to be offered in the iPRODUCE platform.

## 2.5. Stakeholder's Business, Operational and Technical Challenges

The EC acknowledges that common collaborative production challenges include (i) the scaling up of manufacturing to a sufficiently large scale, (ii) the lack of viable business models and (iii) the tension between democratised manufacturing and existing market regulations (EC, 2015). The latter is also connected to issues of safety and quality of community manufactured goods. On top of these macro-

[3] www.thingiverse.com
[4] www.arduino.cc
[5] https://learn.adafruit.com
[6] https://learn.sparkfun.com/resources
[7] https://hackaday.io
[8] https://quirky.com
[9] www.trinckle.com/index. php
[10]https://blog.adobe.com/en/2017/11/29/prototyping-difference-low-fidelity-high-fidelity-prototypes-use.html#gs.k9xuu8
[11] https://sketch.io/sketchpad
[12] https://en.wikipedia.org/wiki/Storyboard
[13] https://en.wikipedia.org/wiki/Hackathon
[14] https://www.businessmodelsinc.com/about-bmi/tools/business-model-canvas

level barriers, a series of subtler interconnected issues exist. Makers struggle between the sharing approach and entrepreneurial one, often causing resistance to scaling efforts. Most importantly, in some cases, perceptions about makerspaces can significantly limit local support and participation.

To construct an appropriate SMF ecosystem is difficult task. iPRODUCE utilizes the knowledge, data, facilities, resources, competences that Manufacturers, Makers and Consumer communities (MMCs) possess. The innovating SMF have to deal with these trilateral collaborations to introduce Open Innovation schemes, where makers and customers take a critical role across the whole process. This role occurs at the innovated design of the product till the manufacturing and production. By employing this envisioned SMF, shorter innovation cycles will arise, enhanced innovation performance, distributed micro-manufacturing facilities and wider market reach. The basic component of the SMF is a network of cMDFs, that involved local OI ecosystems. So, the project integrates the outcomes of social research to understand the dynamics of MMCs motivation and the role that socio-economic and cultural factors plays in their joint co-creation activities within and between local ecosystems. Eventually, it is expected that many barriers and obstacles emerge.

The iPRODUCE surveys performed within D2.1, D2.3 and D2.4 conducted with robust questionnaires which were answered by the MMCs, have identified different obstacles in SMF as business, operational and technical challenges.

**The business challenges that emerge are:**

- Obtaining the necessary funding (economic sustainability).
- Dependency on public funding in many cases. Funding and sustainability difficulties.
- Lack of sustainable and adequate business model (no strategic investments).
- Attracting more users (MMCs) and increasing participation.
- Geographical location or poor access.
- Lack of specialization (in a specific area or sector).
- Lack of connection with other spaces.
- Lack of new ideas, lack of innovation culture.
- Making online and in-person activities compatible.

**The operational & technical challenges that emerge are:**

- Constructing an appropriate SFM ecosystem with open culture
- Lack of persons dedicated to communication
- Digitization of the manufacturing and lack of non-technological tools to facilitate innovation
- Lack of appropriate space and infrastructures
- Organizational and geographic difficulties in attending to users
- Improvement or acquisition of machinery
- Not specializing or seeking new training niches
- Production of customized and personalized products
- Loss of support from the institutions

We expect to have more information on the prevalence and importance of these challenges as the project matures.

# 3. Collaborative Manufacturing Demonstration Facilities

## 3.1. iPRODUCE cMDFs and their Local Ecosystems

iPRODUCE introduces a social manufacturing platform that enables and facilitates multiple stakeholders (manufacturers, makers, consumers/ customers) to support user-driven open-innovation and co-creation. The project organizes its local innovation ecosystems around existing micro-manufacturing facilities and deploy the geography correlation of the stakeholders in order to strengthen collaboration potential. Specifically, within iPRODUCE six different cMDFs are organized with their local ecosystems at six different EU countries as is shown in Table 2.

Table 2 iPRODUCE Collaborative Manufacturing Demonstration Facilities.

| Country | cMDF | Services |
|---|---|---|
| **Spain** | | |
| | AIDIMME and its local ecosystem Lagrama and Oceanonaranja | Physical products design and co-production will be introduced for the furniture domain. Provide a physical space for MMC´s communities to estimulate, promote, and develop innovative customer-driven product ideas in a collaborative way with the goal of transforming them into real furniture products that could be later commercialized. |
| **Germany** | | |
| | Fraunhofer -FIT and its local ecosystem ZENIT, Siemens, Wirtschaftsforderung Bonn (Makerspace) | Design, training and rapid prototyping of electronic devices, focusing on emerging IoT applications for Industrial Environments and/or Smart Cities context based on 3D printed PCBs. Understand and determine the relationship between SME's and Makerspaces to facilitate initial equipment usage of new users. Develop processes and tools to support iterative prototyping with electronics. |
| **France** | | |
| | Materalia and its local ecosystem FabLab-Vosges and Excelcar | Physical products co-creation and co-design in the mobility and automotive sectors Give access to potential users or products developers by creating virtual and digital trainings, tutorials and courses related to product design and manufacturing, and the use of machines and programming software. Support entrepreneurs' and SMEs' projects, especially in the mobility and electro-mobility sectors, by introducing and encouraging them to involve social and collaborative manufacturing in their product design and development processes. |
| **Italy** | | |
| | Trentino Sviluppo SPA and its local ecosystem Energy@Work | Product development/enhancement in the microelectronics consumer sector mainly, in the design and realization of mechatronics and microelectronics appliances. Competences span from mechanical and electronic design, electronics, through cybersecurity, metallic and polymeric 3D printing, measurements, quality control. |
| **Denmark** | | |
| | betaFACTORY IVS and its local ecosystem Manufacture Copenhagen and Copenhagen Business School (CBS) | Customer-oriented consumer-goods manufacturing like co-created social event sites, customized bespoke furniture for housing or office purposes etc. A mobile lab unit containing a set of machines is being put together and equipped to provide a mobile production facility that can be deployed to various locations linked to specific 'maker'/on site production workshops and activities. |

| Greece | | |
|---|---|---|
| | AidPlex<br>its local ecosystem<br>CERTH and<br>OKThess | Physical products design and co-production will be introduced for medical domain like orthopaedic equipment, face shields etc. Training on additive manufacturing equipment and facilitate initial equipment usage of new users and developing processes and tools to support iterative prototyping with electronics, wide variety of materials and technologies. To introduce and highlight the importance and the advantages of social manufacturing, Greek cMDF is going to engage SMEs, entrepreneurs, makers, industrials and potential customers in many collaborative product development projects by organizing innovative and product designing workshops. The products will be enhanced with IoT and AI functionalities. |

Target of the project is the six cMDFs to enlarge their local ecosystems by bring more MMC stakeholders under their local/regional umbrella.

To identify which MMCs take place in local cMDFs and ecosystems, our D2.3 survey found that SMEs (or microenterprises) by 20.4% was the largest group among others as shown in Figure 5.

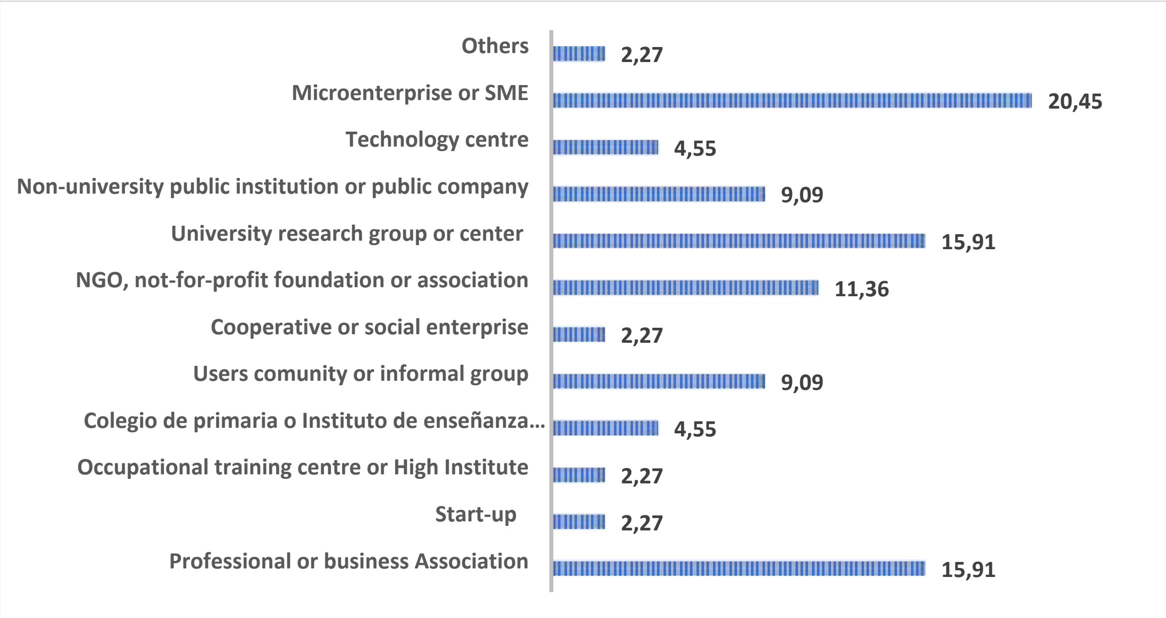


Figure 5: Stakeholder groups involved in SMF local ecosystems.

## 3.2. Federation of iPRODUCE cMDFs

iPRODUCE cMDFs work towards the development of a Lean Operational Model which can in turn lead to the transformation of both Local cMDFs and their Federation. This work will be presented on D3.1, a public deliverable on M24.

The iPRODUCE federation mechanism will serve (a) operational optimization purposes by enabling knowledge extraction and sharing, as well as sharing of resources and of manufacturing facilities; (b) marketing and business purposes by reaching a much wider community of consumers. The latter will open new markets for manufacturers, while it will also allow the use of distributed micro-manufacturing facilities towards 'massive' personalisation of consumer goods. The envisioned federation mechanism will also provide for interoperability for the data models, designs, services and processes of the cMDFs.

### 3.2.1. Governance Principles

The digital platform developed in iPRODUCE will inevitably be deployed in diverse industrial and geographic settings across the EU. The various platform instances will be federated to foster healthy competition and provide users with the benefits of digital automation. In this respect, iPRODUCE is inspired as a catalyst for an ecosystem of commercially viable, but smaller platforms that partly cooperate to deliver value to their users. Such an ecosystem must over time develop governance mechanisms that ensure stable growth and sustainable outcomes. The governance mechanisms for digital platform ecosystems need to reflect on the lawful interactions of key stakeholders: owners of the platforms, companies using the platform, or developers, users and regulators.

In federated ecosystems, the governance mechanisms must also ensure balanced interplay and understanding of interdependencies between all stakeholders, collaborating in such an ecosystem. The federation mechanism must act as a deterrent to monopolistic behaviours and foul-play where certain entities in the platform take advantage of others to establish privileged positions. This means that both platform stakeholders and platform technology enablers must be governed, and that the federation mechanism should support the policy of establishing level playing fields for all entities in the ecosystem.

Overall, governance challenges for platform ecosystems come in many forms and various questions; for example, how to setup membership; who makes decisions about the user role, technology provisions etc.; who maintains the platform instances; how are new services implemented and deployed; who owns the Intellectual Property Rights (IPRs) etc. One of the greatest governance challenges is how to get business competitors to cooperate with each other, within the platform ecosystems. Here, efficiency gains, Return of Investments (ROIs) and other incentives need to be supported through platform ecosystems by selecting the adequate governance mechanisms models[15].

iPRODUCE governance mechanisms consider the inherent characteristics of the Fablab and makers environment. Typically, these environments are composed of loosely coupled entities that part collaborate part compete through ad-hoc communication and collaboration mechanism. The iPRODUCE digital platform, OpIS, in these environments can address aspects common across other environments such as user management, automation, communication, transaction management etc. and aspects as security, privacy and robust IPR protection. To address the complexity of these aspects, OpIS governance elements should cover the following areas:

- User-oriented policies that govern interactions and business relationships. Generally, these policies are delivered through terms and conditions, terms of use, security and privacy protocols, business contracts, user agreement and collaboration agreements. In a platform federation, these documents need to be defined (considering mutual agreements and applicable regulations) and publicly made available in the federation (these policies will be presented and analyzed thoroughly on D2.7 by M18)
- Platform policies that define the rules, trust policies, communication rules and terms of doing business on the platform based on IPR management strategies. (see 3.2.2)
- Data management policies that define the way data is managed, processed/used, stored and exchanged between partners. Data policies need to factor in the sensitivity and regulations associated with personal data and corporate data. (see 3.2.3)

[15] S. Mukhopadhya.et al.,Orchestration and governance in digital plat-form ecosystems: a literature review and trends, Digital Policy, Regulation and Governance, Vol. 21 No. 4, pp. 329-351, (2019)

A part of this work will be performed on D6.1 on M18 and D7.3 on M36 and their results will be used to enrich their mentioned context here by M18 on D2.7 and by M36 on D2.8.

### 3.2.2. IPR Management in a Social Manufacturing Environment

As a starting point, within iPRODUCE the general principles that are considered for managing knowledge and Intellectual Property Rights are based upon and are in line with H2020 Intellectual Property Rights (IPRs) recommendations. The specific rules for IPR and knowledge management are detailed in the project's consortium agreement, which clearly defines the rights and responsibilities in this regard.

Considering the different roles and contributions from the actors that are expected to engage in the iPRODUCE social manufacturing environment, the respective Social Manufacturing Framework should promote a balanced and fair IPRs management strategy that protects the interests of all stakeholders. Particularly, in case of openly shared designs and social manufacturing practices, neither the scientific publications nor the community sites are considering existing patents. The Creative Commons license is commonly recommended and used for newly designed products but there is a lack of considerations towards patents and / or legibility of reverse engineering.

The IPRs management strategy within a social manufacturing framework aims at safeguarding creators and other producers of intellectual goods and services by granting them certain time-limited rights to control the use made of those products. The collaborative nature of Social Manufacturing raises this issue, as questions about legal ownership may occur before, during or after completion of a fabrication process. Therefore, It is essential to highlight possible IPR related risks that can emerge in a social manufacturing environment where co-creation is intrinsically present, but that may effectively inhibit this type of activities. Such risks may include, for example loss of IP rights; exploitation of ideas by the community; use of ideas without proper acknowledgement; and exploitation of ideas by the larger company without recognition or compensation . Furthermore, financial risks are also relevant in such an open innovation environment.

Currently, the risk mitigation strategies that have emerged and been applied for the above mentioned risks, focus on stimulating multi-actor participation and maximising co-creation value. Such strategies include transaction-light partnerships that involve standard IP protection contracts; contracts that formally codify responsibility; balanced control mechanisms; and involvement of brokers to facilitate the co-creation process . In addition to these strategies, initiatives such as Creative Commons and the open-design movement offer other innovation-friendly and knowledge protection tools that can be applied in a social manufacturing environment.

Traditionally, companies developed new technologies for their own products internally either by iterative development or by radical, more innovative, approach that results in new products that are protected with patents. Thus, most companies pursued relatively "closed" innovation strategies, with limited interactions with the outside environment[16].

The legal uncertainty of protection based on intellectual property rights stresses other forms of protection based on business practices. Firms often use alternative forms of protecting knowledge. Commonly these methods of private ordering require contracts or other types of direct behaviour control. However, any contracting for intangible innovation is extremely challenging as the parties would not be able to

[16] Lichtenthaler, Shared Value Innovation: Linking Competitiveness and Societal Goals in the Context of Digital Transformation (2017)

specify the result of their cooperation[17] contracting for these types of innovation may seem highly incomplete even. The incompleteness also makes it difficult to agree beforehand on the sharing of the profits and costs as well as on the ownership and use of the result of cooperation. In contrast to this, contract law based on the model of sale of tangible goods often starts from the requirement to define the object of the contract including the definition of the goods and the price. Intangible innovation and open-ended collaboration are often a poor fit. Furthermore, flexibility, which is the starting point of open innovation, is an exception according to contract law and unclearly defined contract terms can be interpreted as no contracts at all[18].

Since both contract law and IP law offer only weak supports for open innovation, open innovation may require particular innovative capability in firm to manage openness and interface it with the closed innovation model, through private ordering means. Additionally, as business models which build on open innovation may also require a different IP strategy as well as contract policies aligned with the IP strategy and the business model.

iPRODUCE has outlined practical approaches for IPR management through the survey results within D2.1, which performed to stakeholders whether management of Intellectual Property Rights should be addressed in a web platform for social manufacturing. These approaches are also expected to facilitate the formation and management of multi-party ad hoc teams that will work in socially collaborative manufacturing activities.

Table 3 presents the analysed results of the study regarding the Management of IPRs in a Digital Platform for Social Manufacturing. The study clustered by stakeholder groups, pilot countries, gender, and level of education. It is observed that, among the three main stakeholder groups, representatives of manufacturing SMEs are the ones who most eagerly support the option of including this service for safeguarding their projects. With regard to education, people of a higher education – as expected – have expressed a higher preference towards including such a feature. Finally, it appears that participants from Germany and Greece are especially interested in being able to manage IPR through a social manufacturing online platform. In most cases, 1 out of 3 survey participants does not have an opinion.

Table 3 Management of Intellectual Property Rights in a Digital Platform for Social Manufacturing.

| **Do you believe that the Management of Intellectual Property Rights (IPR) should be addressed in a Digital Platform (Web) for Social Manufacturing?** | | | |
|---|---|---|---|
| | Yes | No | Do not Know/ No opinion |
| Total | 58.87% | 10.31% | 30.82% |
| **Stakeholder groups** | | | |
| Consumers/General public | 55.19% | 9.74% | 35.06% |
| Makers & Maker communities | 59.72% | 12.50% | 27.78% |
| Manufacturing SMEs/Industry | 67.20% | 10.05% | 22.75% |
| **Countries** | | | |
| Denmark | 37.50% | 12.50% | 50.00% |
| France | 56.19% | 8.57% | 35.24% |
| Germany | 63.78% | 11.22% | 25.00% |
| Greece | 75.00% | 3.05% | 21.95% |
| Italy | 44.80% | 18.40% | 36.80% |
| Spain | 53.38% | 10.53% | 36.09% |
| **Gender** | | | |
| Male | 58.64% | 11.40% | 29.96% |

[17] Lee, Treatment-Effect Bounds for Nonrandom Sample Selection (2009)
[18] S. Nystén-Haarala, et al., Contracting and business processes (2010)

| | | | |
|---|---|---|---|
| Female | 59.57% | 8.51% | 31.91% |
| Other | 57.14% | 0.00% | 42.86% |
| **Education** | | | |
| Less than a High School Diploma | 42.86% | 0.00% | 57.14% |
| High School Diploma | 42.00% | 15.00% | 43.00% |
| Bachelor's Degree | 58.16% | 6.28% | 35.56% |
| Master's Degree | 62.82% | 11.83% | 25.35% |
| Doctorate | 64.89% | 10.64% | 24.47% |

**Moreover, the stakeholders interested in accessing an IPR management service within a digital platform for social manufacturing** were further asked to define which IPR type would better reflect their individual needs for safeguarding a project.

As depicted in Figure 6, it appears that patent and copyright options are considered to be equally popular. A share of 17.5% expressed that smart contracts would better reflect their needs whereas only a 7.7% share chose trademark as the preferred IPR type.

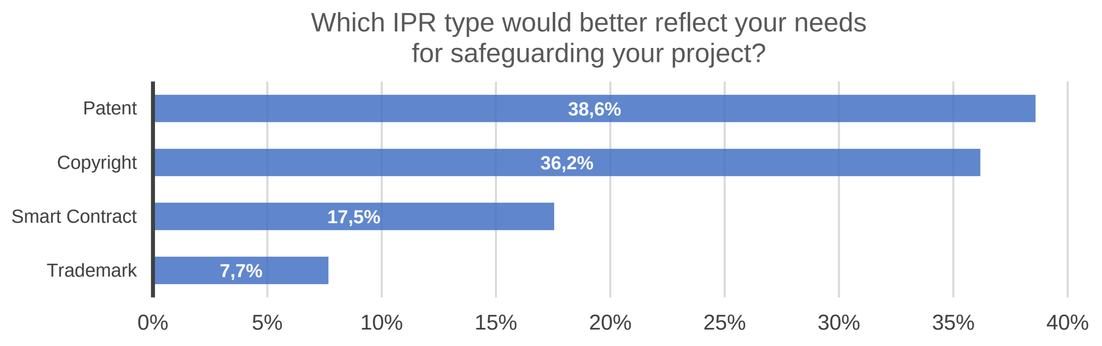


Figure 6: Preferred IPR type in a Digital Platform for Social Manufacturing.

Overall, independently of the variable assessed (country, stakeholder group, education, and age), there is a tendency in most cases for the copyrights and patents to be the preferred option for IPR protection, which are also the most traditional mechanisms. However, the numbers collected for smart contracts across all clustered groups indicate some knowledge on this type of protection and, in some cases (e.g. Denmark), a clear preference for this option.

While the numbers suggest that the preference is towards traditional protection mechanisms, it can also be argued that smart contracts are an emerging option not known to many (those inquired and other potential stakeholders). For this reason, it remains a valid option to be exploited by iPRODUCE.

In summary, based on these results, not only is the development of a platform to facilitate IPR management relevant, but also alternative mechanisms (e.g. smart contracts/ Ricardian contracts) are valid solutions that should be explored, although the principles of the more traditional protection mechanisms should still be considered in this process.

At this stage, blockchain and smart contracts can help execute predefined rules and facilitate workflow automation, thus reducing resources and bureaucracy. Likewise, Ricardian contracts are also relevant, and similarly to smart contacts, aim to define a set of rules of an agreement between actors. However, smart contacts and Ricardian contracts target different aspects of this process. The former is machine-readable code and thus track the flows and events of the process; the latter are human readable and understandable by non-tech-savvy actors and offer closer definitions to the real-world agreements between participating actors.

**Based on the experience of iPRODUCE partners, one strategy to adopt for IPR management through digital platforms like OpIS, is the use of Distributed Ledger Technologies (DLT) and more specifically Ricardian Contracts**. It is considered that the Ricardian contract has three advantageous aspects, namely their robustness, transparency, and efficiency. Within the iPRODUCE and the social manufacturing environment, the development of a Ricardian Contract considers the use of a visual authoring tool to help define a set of rules that are used in the design thinking process for the (social) co-creation of a product. Specifically, it is first necessary to define the entities/ actors involved in the co-creation of a product. Second, it is necessary to divide the co-creation process into business flows with different weights and allocated objectives. Thirdly, governance policies are defined, including requirements for approval of an entity/actor's contribution to completing an objective/ business flow. Fourth, it is necessary to provide a platform for the management of entity/actor's implementation of objectives/ business flows. Lastly, once all business flows have been completed, the entities will be accredited based on the weight of the objective/business flow to which they contributed.

With this framework in mind, iPRODUCE explores the integration between the mentioned Ricardian contracts and smart contracts by developing a dedicated visual authoring tool that will encode human readable language (Ricardian-type) into machine readable language (smart-type), and ultimately delivering a solution that can contribute to the IPR management process required for a trustworthy social manufacturing environment. This and other approaches will be explored over the course of the project to identify the one that addresses the greatest number of requirements identified.

### 3.2.3. Data Management Policies

For as far as Social Manufacturing has existed it has always relied on data to make its findings. This management implies having knowledge of the value of datasets for the co-create actions and developments, for the evaluation of research and for commercial undertakings.

The iPRODUCE Data Management Plan (DMP) is based on the updated version of the "Guidelines on FAIR Data Management in Horizon 2020 version 3.0 released on 26 July 2016 by the European Commission Directorate – General for Research & Innovation". All iPRODUCE data are following the General Data Protection Regulation (GDPR) which applied across the EU from 25 May 2018.

iPRODUCE cMDFs are infromed of the ethical implications of the proposed research and respects the ethical rules and standards of HORIZON 2020 and their obligation to comply with the Charter of Fundamental Rights of the EU. The cMDFs and OpiS should observe Directive 1995/46/EC on protection of individuals with regard to the processing of personal data and on the free movement of such data, and Directive 2002/58/EC on privacy and electronic communications.

All consent procedures within iPRODUCE SMF are carefully determined and managed by pilot-specific tasks that manage the trials which are performed in selected cMDFs. Thus, it requires the enrolment of people voluntarily declaring their consent to participate in each of the pilot use cases. However, the design of the observational study is prepared in strict collaboration with the ethical helpdesk of the iPRODUCE consortium, in order to respect privacy and ethical issues implied by the data to be collected and analysed.

The consent procedure for the pilot use case realisation at each of the selected cMDFs will be obtained through a two -stage procedure:

1. Initially the pilot trial's leader will orally present the pilot to the people that will be involved, carefully describing the level of privacy infringement that the execution of each of the pilot realisation involves. In case someone wants to exercise his/her right not to know, he/she will be excluded from the pilot.
2. Secondly, after a few days, subjects will be required to read and sign an informed consent form that will explain in both plain English and in local language what the trial leader has already orally explained. The informed consent forms in English and in local language to be used will be sent to the European Commission and included in the experimental protocol.

### 3.2.4. Healthy and Safety

Collaborative manufacturing shares many of the risks typical for manufacturing work but does not enjoy the same level of protection from this risks that traditional workers do. While ad-hoc safety policies (also including training) are implemented in some Fablabs, it is unknown of whether these can cover work that is done outside the physical building or that it does consider risks associated with specific populations. Occupational safety and health practices are necessary to assess the risks throughout the collaborative production chain. iPRODUCE will rely on existing practices and will tailor the most fitting ones to the specific requirements of each separate pilot case (cMDF) Research activities in iPRODUCE comply with the applicable international, EU and national law as the EU Directive 89/391/EEC, that guarantees minimum safety and health requirements at work throughout Europe (Member States are allowed to maintain or establish more stringent measures)..

As part of this project policy, the approach to Health and Safety issues at the cMDFs is expected to be flexible enough to take into account any new ethical or safety issues that may arise. The risks in the research activities will be continuously updated by the cMDFs, and whenever needed, guidelines and procedures will be updated accordingly. The cMDFs as a starting point will apply a risk assesment to identify all the hazards derived from the development of the use case scenarios. Whether the risk assessment identifies the need for special skills or competences in the development of the activity, the appropriate training actions should be carried out at each cMDF. (I.e. when the assurance of safe operation of electromechanical equipment requires a minimal level of training and expertise, each partner entity shall put in place formal procedures to certify individual operators of that equipment). Each use case scenario must be evaluated from the Occupational Risk Prevention (OPR) point of view to adopt the preventive measures, based on the activities to be developed, equipment to be used, chemicals involved, etc.

The risk assessment allows iPRODUCE SMF through the evaluation of:

- Workflow: all actions of the research participant and the expected system responses for planned normal execution of the research scenario. Alternative flows (usually the result of options or exceptions) will also be assessed.
- Health and safety conditions in the research site
- Installations, equipment and machinery required to carry out the activity
- Physical, chemical or biological agents affecting the research site
- Coordination of preventive activities
- Regulatory compliance for any other circumstance.

# 4. iProduce Architecture Reference Model under Open Innovation

Social manufacturing, as a form of new next generation manufacturing paradigm is a variety of service-oriented manufacturing and inherits all the natural characteristics of the service-oriented manufacturing[19]. The basic architecture of social manufacturing paradigm is a distributive, social-media-like and service-oriented, and works under the environment of the socio-technical system.

The project uses the current state-of-the-art social engagement practices, relevant ICTs and manufacturing technologies, synchronize them in order to function together under a digital Open Innovation Space (OpIS) for personalised products and fast prototyping. iPRODUCE social manufacturing platform, OpIS, is a software application that provides function modules of socialized manufacturing resources and outsourced manufacturing services.

Also, the OpIS social space integrated with digital social networking tools for open product design to enable the correspondent product manufacturing activities dealing with the designing stage of a product life cycle and also influence deeply the runtime logic in the other stages. Another important characteristic of OpIS social manufacturing paradigm is Internet-based, since involves social interactions, social context, and social relationships of enabling Internet-based connecting and communicating behaviors in business view. Under the above characteristics, OpIS found to be a digital manufacturing platform for open product design based on a social co-creation framework.

The main architecture models for digital Manufacturing Platforms that have been identified as reference for the iPRODUCE SMF are the:

1. Reference Architecture Model Industry 4.0 (RAMI4.0)
2. Smart Manufacturing Ecosystem reference model by National Institute of Standards and Technology (NIST)
3. Industrial Internet Reference Architecture Model (IIRA)

## 4.1. Reference Architecture Model Industry 4.0 (RAMI4.0)

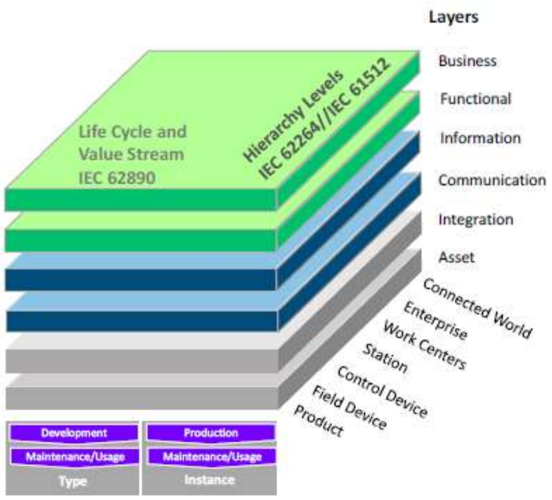


Figure 7: Reference Model for Industrial 4.0 (RAMI 4.0) reference model layers[23].

[19] Pingyu Jiang, Social Manufacturing: Fundamentals and Applications pp 13-50, (2019)

RAMI 4.0[23] is based on a three-dimensional coordinate system consisting of the Layers, Life Cycle & Value Stream, and Hierarchy Levels dimensions, which is represented below in Figure 7. This structure is a service-oriented architecture-based interfaces which can be regarded as a standardized digital representation of any technical asset of a factory asset and can be used to systematically organize and further develop I4.0 concepts and technologies.

## 4.2. Smart Manufacturing Ecosystem reference model by National Institute of Standards and Technology (NIST)

The Advanced Manufacturing Series (AMS) of standards by NIST provide the Smart Manufacturing Ecosystem as a reference model for digital manufacturing platforms. The NIST Smart Manufacturing Ecosystem defines a four-layer model which can be mapped to the RAMI 4.0 layers as is shown in Figure 8 [20]. The NIST reference model is based on ISA95 model and includes the AMS 300-4 Guide to Industrial Wireless System Deployments[21] and AMS 300-6 Securing the Digital Threat for Smart Manufacturing[22] by providing additional guidelines from RAM 4.0 for the configuration of wireless networks and block chain-based product data traceability.

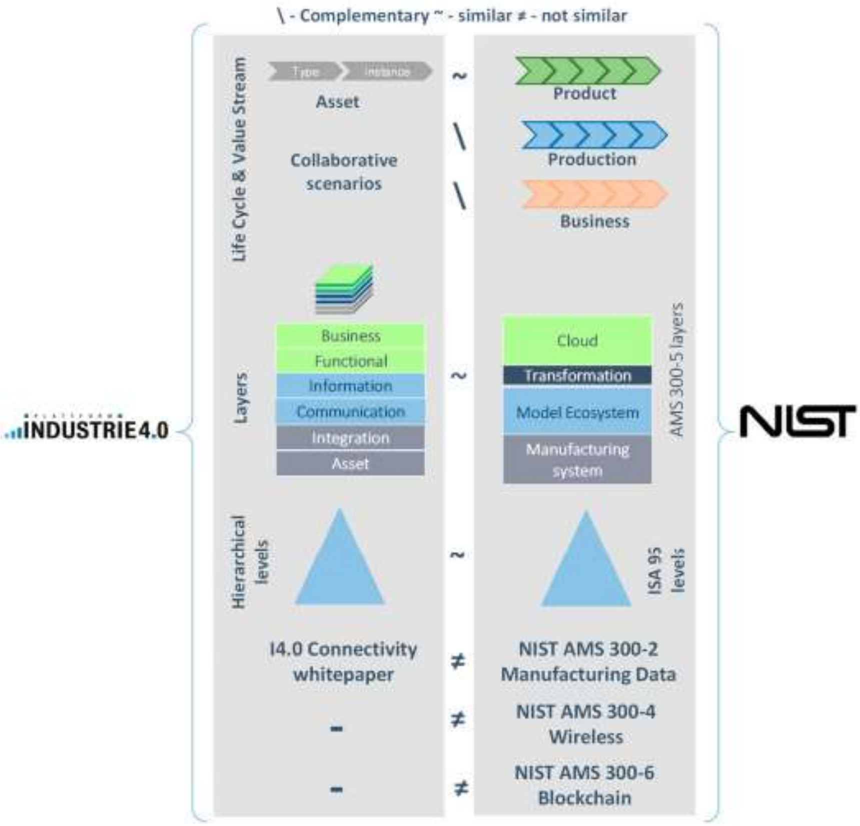


Figure 8: Alignment of RAMI 4.0 and NIST reference model- Smart Manufacturing Ecosystem.

[20] F. Fraile, et al., Reference Models for Digital Manufacturing Platforms Appl. Sci. 2019, 9, 4433
[21] American National Institute of Standards and Technology. Guide to Industrial Wireless Systems Deployments; American National Institute of Standards and Technology: Gaithersburg, MD, USA, 2018.
[22] American National Institute of Standards and Technology. Securing the Digital Threat for Smart Manufacturing: A Reference Model for Blockchain-Based Product Data Traceability; American National Institute of Standards and Technology: Gaithersburg, MD, USA, 2018.

Figure 9a illustrates the three dimensions of NIST Smart Manufacturing Ecosystem model[23], product (green), production system (blue), and business (orange) within its own lifecycle:

- product lifecycle regards the information flows and controls begging at the early product design stage and continuing through to the end-of-life of the product
- production system lifecycle focuses on the design, development, operation and decommissioning of an entire production facility including its systems
- business cycle addresses the functions of supplier and customer interactions.

Each of these dimensions comes into play in the vertical integration of machines, plants, and enterprise systems in what we call the Manufacturing Pyramid as is shown in Figure 9b[26], which is aligned to the IEC 62890 product life-cycle model Instance Production phase.

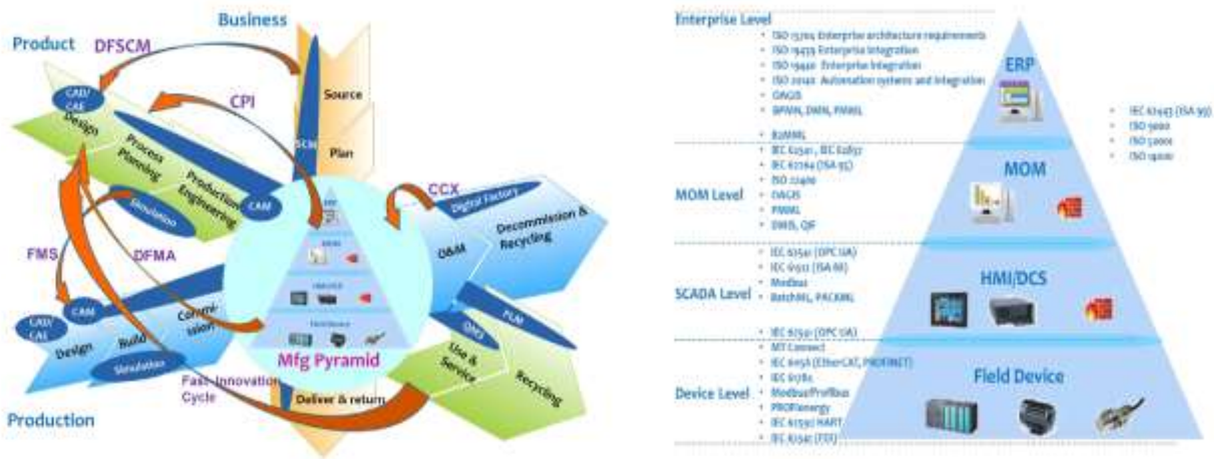


Figure 9: Smart Manufacturing Ecosystem aligned to IEC 62890 and ISA95 model.

## 4.4. Reference Architecture Model IIRA

The IIRA model [24]specifies an Industrial Internet Architecture Framework (IIAF) based on 'ISO/IEC/IEEE 42010:2011'. The IIAF identifies conventions, principles and practices for consistent description of IIoT architectures. This standard-based architecture framework facilitates easier evaluation, and systematic and effective resolution of stakeholder concerns. Using IIRA approach to architecture design assists in consistent architecture implementation across different use cases in various industrial sectors meeting unique system requirements. Equally importantly, it assists in achieving a common understanding and communication of the overall system among its diverse stakeholders, which will aid in system deployment and significantly enhance system interoperability across industrial sectors.

The IIRA viewpoints as shown in Figure 10, are defined by the Industrial Internet Consortium (IIC) based on the identified use cases and relevant stakeholders of IIoT systems.

**These four viewpoints are the:**

• Business Viewpoint

[23] NISTIR 8107 Current Standards Landscape for Smart Manufacturing Systems, doi.org/10.6028/NIST.IR.8107
[24] The Industrial Internet of Things Volume G1: Reference Architecture Version 1.9 June 19, 2019

- Usage Viewpoint
- Functional Viewpoint
- Implementation Viewpoint

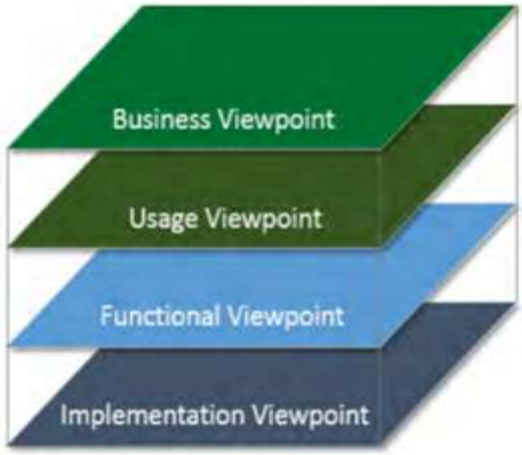


Figure 10: Industrial Internet Architecture Viewpoints.

**Business Viewpoint**

The business viewpoint attends to the concerns of the identification of stakeholders and their business vision, values and objectives in establishing an IIoT system in its business and regulatory context. It further identifies how the IIoT system achieves the stated objectives through its mapping to fundamental system capabilities. These concerns are business-oriented and are of particular interest to business decision-makers, product managers and system engineers.

**Usage Viewpoint**

The usage viewpoint addresses the concerns of expected system usage. It is typically represented as sequences of activities involving human or logical (e.g. system or system components) users that deliver its intended functionality in ultimately achieving its fundamental system capabilities. The stakeholders of these concerns typically consist of system engineers, product managers and the other stakeholders including the individuals who are involved in the specification of the IIoT system under consideration and who represent the users in its ultimate usage.

**Functional Viewpoint**

The functional viewpoint focuses on the functional components in an IIoT system, their structure and interrelation, the interfaces and interactions between them, and the relation and interactions of the system with external elements in the environment, to support the usages and activities of the overall system. These concerns are of particular interest to system and component architects, developers and integrators.

**Implementation Viewpoint**

The implementation viewpoint deals with the technologies needed to implement functional components (functional viewpoint), their communication schemes and their lifecycle procedures. These elements are coordinated by activities (usage viewpoint) and supportive of the system capabilities (business viewpoint). These concerns are of particular interest to system and component architects, developers and integrators, and system operators.

## 4.5. iPRODUCE Reference Architecture Model Approach

iPRODUCE partners according the literature study on the existed reference architecture models for digital platforms mentioned above, consider that the best reference model approach to use for the OpiS architecture is the Industrial Internet Reference Architecture Model (IIRA).

The OpIS architecture has been designed with consideration to compliance with Industrial Internet Reference Architecture Model (IIRA) since IIRA, is used for integration of research and technical development efforts in the area of industrial IoT systems and complex platforms which involve several stakeholders. This collaboration and integration with other initiatives is a strategic objective of the project. The iPRODUCE Reference Architecture Model Approach adhere to the ISO/IEC/IEEE 42010:2011 standard, using several viewpoints to frame the concerns of the system stakeholders and illustrate the design decisions taken. A first iteration of the OpIS architecture design according IIRA viewpoints is shown on Figure 11.

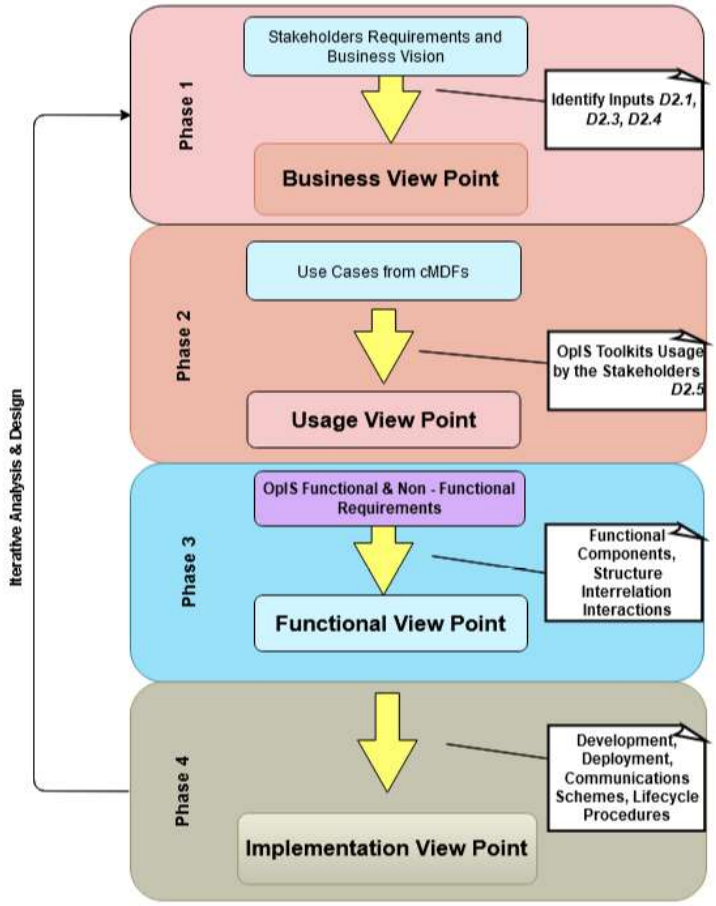


Figure 11: Architecture Design Methodology (First Iteration).

**Phase 1:** Focuses on the business viewpoint and addresses the stakeholders concerns and requirements which are business-oriented. The first iteration concerns derived from WP2 results, specifically from the deliverables D2.1, D2.3 and D2.4 of the iPRODUCE project. The second iteration will be enriched by the results which will be derived from D2.2, D5.1, D6.1, D7.1 and D7.2 by M18.

**Phase 2:** Focuses on the the usage viewpoint which addresses the concerns of expected OpIS usage. The first iteration based on the information for the use case definition within D2.5. The second iteration will be enriched by the results which will be derived from WP3, D2.2, D5.1, D7.2 and D9.1 by M18.

**Phase 3:** Focuses on the functional viewpoint which deals with the fuctionality of the OpIS componets, their structure, interrelation, interfaces and interactions between them as well as with the enviroment. As first step of this phase, a template has been defined in order to collect a short description of all components and sub-components, functional and non - functional requirements, related services, dependencies, inputs needed and outputs provided brought by the partners. As a second step of this phase, the relevant partners deployed a functional view of the sub components of each main component of OpIS. At the second iteration the functional viewpoint will be enhanced with the progress of the components structure and interrelation through the WP4, WP5, WP6 and WP7.

**Phase 4:** Focuses on the implementation viewpoint which deals with the technologies needed to implement the functional components (functional viewpoint), their communication schemes and their lifecycle procedures. These elements are coordinated by activities (usage viewpoint) and supportive of the system capabilities (business viewpoint).

The results of the first version of the software architecture design activities for the OpIS relevant to its Business, Usage and Functional Viewpoint are reported in the confidential deliverable, D4.1: "OpIS Architecture & Design for Social Manufacturing I" on month 9. The OpiS finalised architecture and design will be followed by the D4.1 "OpIS Architecture & Design for Social Manufacturing II" on month 27, providing an updated description at these viewpoints, the deployment and the finalization of the Implementation Viewpoint and how future architecture design will proceed.

# 5. iPRODUCE's Social Manufacturing Building Blocks

## 5.1. iPRODUCE Platform Main Components

The OpIS integrates main components which support knowledge and resource sharing across cMDFs, ideal for use under a social manufacturing framework. The cMDFs are connected with OpIS through novel co-creation methodologies, training toolkits and sharing-economy business models to adapt the organizational systems, shape the social manufacturing processes and scale collaborative production activities.

The Table 4 that follows provides a description of the main components of the OpIS to understand better their usage and functionality.

Table 4: iPRODUCE Main Components.

| Component | Description |
|---|---|
| **Generative Design Platform** | Digital toolkit to explore a solution space which adheres to a provided ruleset of constraints and enables the engineer / designer and user to innovatively, engagingly "breed" the final, personalized solution together |
| **Ricardian Toolkit** | A blockchain toolkit which is used for developing smart contracts as Ricardians. The Ricardian toolkit method based on expressing, encoding, and executing a contractual document through software, which means that it represents the recording of documents as contractually lawful, and then securely linking them to other ambits/systems, such as of accounting, for the contract to serve as an issuance of value. |
| **Marketplace** | The marketplace will provide the ability to register new users (makers, communities) where each can edit each own profile & list of ideas / products. |
| **Matchmaking** | The matchmaking will allow the platform users to find suitable partners, products and services to enable the development of agile collaboration networks. |
| | The agile network creation tool will operate in conjunction with the Matchmaking tool as it supports the creation of collaborative networks that can jointly address specific business opportunities. |
| **AR / VR Toolkit** | Is real time social manufacturing space for co-creation process under Augmented and Virtual environments. Deals with the end – user interfaces and services product design, provide assistive, decision support and risk management features. |
| **Mobile App** | A mobile application is developing to obtain Voice of Customer feedback through which iPRODUCE can actively solicit input about new ideas, stress test existing ideas, etc. |
| **Agile Data Analytics &Visu-alization Suite** | The main goal of the agile data analytics is the design and development of an Agile Data Analytics and Visualization suite, with a specific focus on Big Data (e.g. Analysis of the feedback from the cMDFs potential users, trainees, user preferences about the products/services, market trends, datasheet and technical manual of equipment etc) |
| **Digital Fablab Kit** | Toolset for digitizing existing knowledge and common practices in makerspaces. It mainly addresses two aspects: (1) Digitization of training activities and (2) Digitization of production processes. |
| **OpIS Data Repository** | This tool covers the data access, security, exchange and analytics within iPRODUCE which are necessary, as a prerequisite for collaborative production. |

The Consortium's approach for designing a complex platform under SMF, is to decompose OpIS into the constituent main components. A component diagram as shown in Figure 12 is used to describe the structure of the main components in OpIS at a high-level functional view.

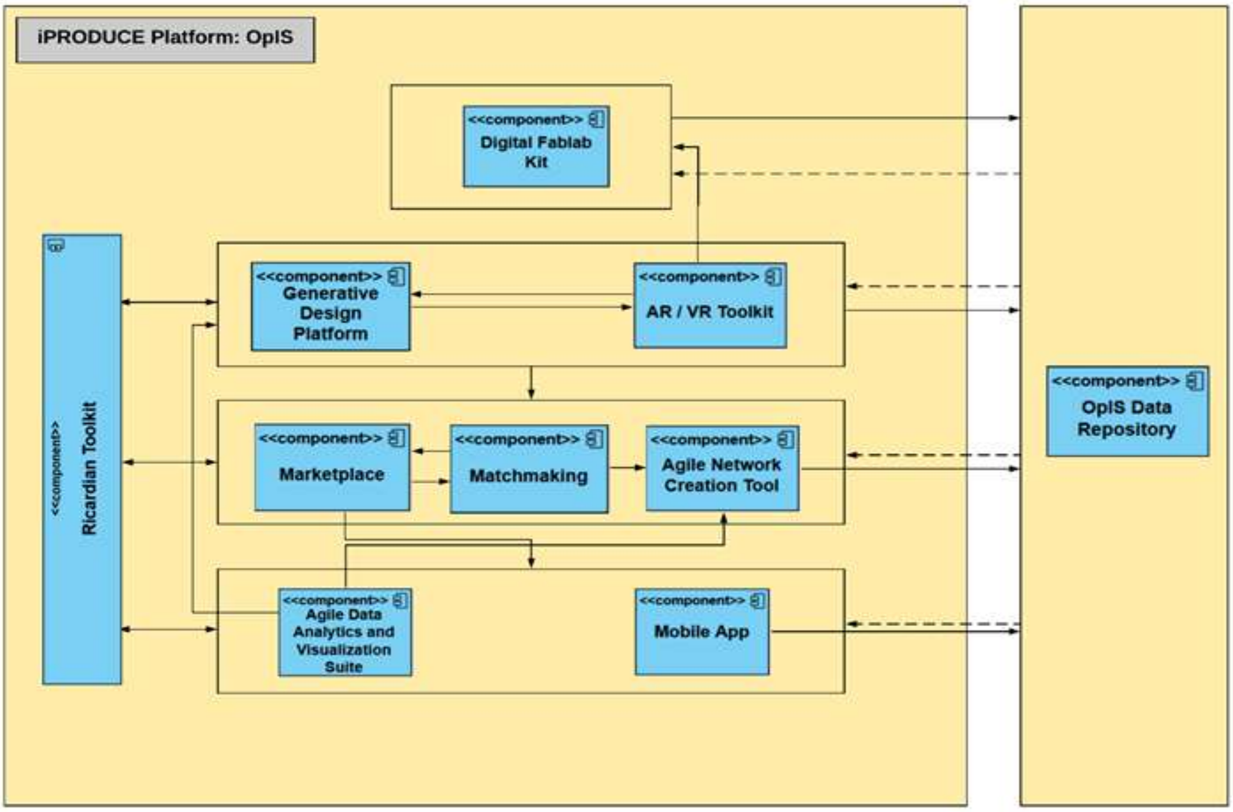


Figure 12: OpIS main components diagram (high-level functional view).

## 5.2. iPRODUCE Main Component Address the SMF Challenges

The D2.3 survey reveals social manufacturing spaces with succeed stories as the Fab Café, FabLabs Social, Labfab Université de Rennes 1 and Atelier FabLab Kamp-Lintfort. These social manufacturing spaces were established to become places where people of all ages and disciplines could meet and manufacture everything, they had previously thought was impossible, using digital tools, in a creative atmosphere full of synergies. From these spaces derived some best practices useful to be considered to iPRODUCE main components functionalities:

- Bring digital creation and the maker culture to young persons.
- Provide a place equipped with technological tools and sources of innovation.
- Customized events depending on the requirements of the project (Collaborative manufacturing, team training workshops for companies, original events).
- Workshops on purpose competitions and challenges. The learning method is through combined practical-theoretical sessions, with challenges addressed by teams, empowering participants so that they are much stronger together.
- Training programs for learners to acquire skills.
- Free and tremendous training resources available for different fields.
- Support for setting up a service, product or start-up

iPRODUCE through the establishment of the Collaborative Manufacturing Demonstration Facilities, the cMDFs (see §2.4), enables multi-stakeholder interactions and collaborations to support user-driven open-innovation and co-creation based on DIY manufacturing.

From their structure and scope as described on session §3 and §4, cMDFs tackle many of the business, operational and technical challenges aforementioned on §2.4. The cMDFs construct an appropriate SFM ecosystem with open culture since allow the open access to many stakeholders in appropriate facilities for micro-manufacturing services, training activities on how they can use a machinery, design a product up to enhance their businesses since these cMDFs participate in a robust marketplace of OpIs. The challenge as production of customized and personalized products is tackle though the Generative design Platform and AR/VR Toolkit development and integration on OpIS. Communication of makers be more effective with manufacturing spaces as cMDFs through the development of the OpIS Mobile application which obtains Voice of Customer feedback. Challenges as organizational and geographic difficulties in attending to users are tackled since the cMDFs spread at six different countries and their organization federation model will be promoted after iPRODUCE to be adopted and from other EU countries on regional and local level. Geographic difficulties also will be mitigated through the Matchmaking and Agile Network Creation Tool under the support of Agile Data Analytics & Visualization Suite since enable users to choose the closest to them region/local cMDF with these services and products of their preferences. Through the provision of the Digital Fablab kit on OpIS user's benefit digitization of training activities and digitization of production processes, thus avoid the need to physically attend to a cMDF space. Under OpIS sharing economy and co-creation processes a strong IPR management through smart contracts and blockchain technologies using the Ricardian toolkit will be provided to protect users.

The main components of the iPRODUCE platform address all the SMF challenges and promote and boost social manufacturing actions and vision as follows below:

### 5.2.1. "Do it Together"

iPRODUCE robust main components as the Generative design Platform, AR/VR Toolkit, Mobile application and Digital Fablab Kit showcase the potential of -"Do it Together" under a blockchain based toolkit which applies Ricardian contracts for contractually lawful IPR protection, through software (Ricardian Toolkit) - to solve operational and technical challenges and thus business by:

1. providing assistance to new companies,
2. develop additional networking
3. having good communication for the exchange of ideas and information,
4. the national and international visibility of each facility, and
5. building a more credible business model in terms of marketing and financing.

### 5.2.2. Connection with Other Social Manufacturing Spaces through OpIS

As it emerges from D2.3's Survey Analysis the European spaces collaborate and work with different types of organisation, especially non-educational public institutions (84% of all the cases). They are followed equally, at 75%, by companies and individuals' persons, and at a distance by educational institutions (54.5%). Little work is done with neighbourhood associations (38.6%) or NGOs (36.3%). iPRODUCE introduce digital Open Innovation Space (OpIS) that accommodate all the functionalities of local cMDFs. OpIS platform contains the Open Innovation marketplace supported by tree other robust tools as the Matchmaking, Agile Network Creation Tool and Agile Data Analytics & Visualization Suite where the local cMDFs can publish their profiles, co-creation offers/ requests and missions; the OpIS tools can help manufacturers identify the most suitable 'lead users' among the makers communities by applying social media mining to user generated content (UGC); the knowledge capturing and sharing component (open access knowledge base); the collaborative resources and facilities sharing component; and the training toolkit on social manufacturing and open design. iPRODUCE builds its social manufacturing approach on the basis of local ecosystems where cluster MMCs, and interlink available micro-manufacturing equipment and building facilities into cMDFs. Geographical proximity plays a key role in the operating effectiveness of such ecosystems. Their members are expected to meet and interact physically within the cMDFs. While iPRODUCE provides a number of digital collaborative tools as Generative design Platform, AR/VR Toolkit, Mobile application and Digital Fablab Kit; physical interaction is expected to strengthen the bonding and overall innovation performance of the co-creation missions that members of each cMDF will undertake. The iPRODUCE to boost ths approach will develop local strategies and business models that will ensure the smooth and effective operation of the local ecosystems, as well as the optimum utilisation of the resources of the respective cMDFs.

### 5.2.3. Digitization on Processes to Facilitate Innovation

According to D2.1's Survey Analysis the 1 out of 3 respondents believes that a potential issue hindering participation in social manufacturing would be the lack of suitable digital technologies, such as platforms and tools. A main problem of the manufacture industries is that the processes not digitalized and there is a gap of tools to facilitate innovation.

The responses in D2.4's Survey Analysis reveal which tools are used (see §2.3), and how and when they are applied in their current production processes, while also shows information regarding hardware and other tools they have at hand when developing products. Concerning open innovation tools, respondents used in a daily bases self-developed project management system so to keep track of project status, self-developed cloud for sharing and slack software for communication.

iPRODUCE creates digital component solutions as described on Table 3 to achieve collaboration activities which contains design tools for shorter design and validation periods, an AR/VR space for synchronous co-working and interaction between MMCs at the whole design and innovation cycle, agile analytics for visualize insights and data generated by the iPRODUCE users and a tool in order to organize the product innovation cycle.

iPRODUCE provides access to individual, small and medium makers who do not possess experimental equipment and facilities with the necessary means to do it and accommodate their creativity and entrepreneurial needs. Thus, the quality of life (of makers) will be improved by providing makers the means to promote their innovations through cMDFs and iPRODUCE platform and achieve economies of scale.

### 5.2.4. Design Thinking, New Ideas, Co-creation & Funding Opportunities

As it emerges from D2.1's Survey Analysis the 1 out of 3 respondents expressed concerns about sharing sensitive information (e.g. technical features of a product, invention/ idea, the design of a product) within collaborative manufacturing communities.

The concept of Design Thinking, which has been popularised across industries in the first two decades of the 21st century, is also presented as a product and service development methodology alongside co-creation and co-production approaches.

There is a lack of a community that collaborate and create innovated ideas and an innovation culture. iPRODUCE project tries to connect and create a collaborative environment between makers and industry. Collecting data to the Agile Data Analytics & Visualization Suite, OpIS component, to understand the motivation, goals and the need of makes and potential makes in order to achieve a transition of a consumer to become a prosumer and of makers to become a co-innovator of SMEs.

From D2.3's Survey Analysis the standout result is that many spaces do not have anyone dedicated to communication (47%), and if they do, most are not specialised (25%). Only 15.9% have their own specialised personnel, and only 11.3% outsource these functions. With respect to communication resources, the survey shows a distribution that is marked by digital tools (available to 65.9%) and only 15.9% do not devote any resources to communication the appearance of the spaces in the media is mainly through interviews (79.5%) and the daily news or current affairs in written or digital press (63.6%). Of those surveyed, 6.8% do not appear habitually in the media. Regardless of appearance in the media, the type of communication with the public or users in the spaces surveyed is mostly through social networks (90.9%) and e-mail (88.6%). Written communication by mobile phone is also a significant resource, being used in 63.6% of the cases.

There is an increasing amount of evidence indicating that using social media in product innovation can lead to leads to better product ideas, better requirements' identification, faster time to market, lower costs, etc. Task 6.2 aims to enhance our generative design processes by collecting and analysing marketplace feedback of maker and consumers communities with regards to our use cases and our solution space. To this end this task aims to develop a mobile app for obtaining Voice of Customer feedback through which we can actively solicit input about new ideas, stress test existing ideas, etc., and passively obtain insights for recurring problems, needs and preferences, etc.

iPRODUCE to boost design thinking, new ideas and innovation and co-creation in product design and manufacturing under its digital platform OpIS, introduce an alternative IPR management strategy. This IPR strategy is translated to rules, roles and activities which is including to the innovative digital tool Ricardian Toolkit which streamlines and automate interaction. Ricardian Toolkit use distributed ledger technologies (blockchain) and generates Ricardian contracts that will translate conventional agreements into smart contracts (for automated transactions).

As it emerges from D2.1's Survey Analysis the 58% share of the survey respondents is concerned about potentially limited funding opportunities, expressing that this could discourage them from taking part in a makerspace. iPRODUCE by generating an adequate IPR management to OpIS by Ricardian Toolkit and sustainable business models will automate multi-stakeholder interactions, spread B2B and B2C synergies and thus funding opportunities.

### 5.2.5. Digital Training and Increase Users Participation by Digitization

As it emerges from D2.1 survey analysis interestingly enough, more than half of responders believes that they do not lack the necessary skills to be involved in makerspaces' activities. This statement is well-aligned with the perception expressed by more than 30% of responder's sample that, in practice, consumers do not lack the necessary knowledge to be part of a manufacturing process.

The lack of technical skills also seems to be an important barrier since "creating an object from scratch using a digital drawing means is not necessarily a straightforward process". As such, this process makes it difficult for anyone to walk into a makerspace and start creating immediately[25]. Potential makerspaces' participants are also concerned about more general contextual aspects, since they perceive makerspaces to be too loud, dusty, and disorganised workspaces.

Apart from the above factors, maker movement gathers rather homogeneous audiences while it appears difficult to attract low socioeconomic or minority groups. In relation to gender, potentially existing gender

[25] Waldman-Brown, A. N. N. A., Wanyiri, J., Adebola, S. O., Chege, T., & Muthui, M. (2016). Democratizing technology: the confluence of makers and grassroot innovators. In Third International Conference on Creativity and Innovations at/for/from/with grassroots-ICCIG.

gaps might arise mostly due to existing norms related to gender imbalances, stereotypes, and biases. From previous studies[26,27] on 2015, have been founded that makerspaces are a male-dominated environment in which women face difficulties in finding a role. To this evidence, iPRODUCE survey on D2.1 by 2020 also concludes that at makerspaces have a much larger share of male (69.26%) compared to the female (28.77%) survey population. The reason of the low-level participation of females at makerspaces is ascribed to lack of technical skills and related careers closely related to STEM[31] and because female makers struggle to find free time to join makerspaces due to family[28].

Furthermore, people with disabilities[29] found makerspaces difficult to access and participate on co-creation and training activities.

iPRODUCE by OpIS components as the digital toolkits, Digital Fablab Kit, Generative Design platform and AR/VR toolkit enhance training and co-creation activities to be held by all groups (people with lack of technical skills, women and people with disabilities) digitally, remotely and without physical presence.

Specifically, the Training Support Tool of the Digital Fablab Kit using video intelligence and highly specializes services, maximizing the prerogatives of Augmented and Virtual Reality, in order to support users in a more effective and appealing way enables (1) digitalization of workshop results, tutorials and methods, (2) user manuals and hands-on best practices for machinery, tools and material, (3) knowledge-, material-, and machinery-exchange, and (4) training in conduction specific operation procedures without having physical access to the makerspaces.

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[26] J. Lewis, Barriers to women's involvement in hackspaces and makerspaces, (2015). Access Space. Retrieved from http://access-space.org/wp-content/uploads/2017/04/Barriers-to-womens-involvement-in-hackspaces-and-makerspaces.pdf

[27] V. Bean, et al., An exploration of women's engagement in Makerspaces. Gifted and Talented International, 30(1-2), 61-67, (2015)

[28] J. Maric, The gender-based digital divide in maker culture: features, challenges and possible solutions. Journal of Innovation Economics Management, (3), 147-168, (2018)

[29] J. Seo, Is the Maker Movement Inclusive of ANYONE? Three Accessibility Considerations to Invite Blind Makers to the Making World. TechTrends, 63(5), 514-520, (2019)

# 6. Conclusions

This document D2.6 provides the evaluation framework and architecture definition and evolution (MS3 -M9) in the form of a position paper. The holistic visionary of iPRODUCE social manufacturing reference model, as a first version documented by month 9.

Further improvement and enrichment of this first version will be follow by month 18, D2.7 "iPRODUCE Social Manufacturing Vision and Reference Model II", where methodologies that drive the engagement of makers and consumers for the establishment of the local ecosystems and makers, the federation structure of the cMDFs and further stakeholder requirements for user-driven innovation in the consumer goods products will be provided. On, the last version D2.8 "iPRODUCE Social Manufacturing Vision and Reference Model III" on month 36 will be included the business models that will be developed covering iPRODUCE cMDFs cases and processes and the deliverable will be able to be used as a Social Manufacturing Reference Model and Framework Evolution paper to enhance the maker and Do-It-Yourself (DIY) movement and co-creation activities and collaboration for manufacturing consumer goods.

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