
# D9.2 Evaluation Methodology, Plan and Metrics 2

AIDIMME

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| **Abstract** | D9.2, along with D9.1, can be regarded as the "official guide" to commence with the evaluation process whose main outcome will be recorded in D9.3 (M33) "Final Evaluation Report of the iPRODUCE digital platform" during next task T9.2 starting on July-21.<br>This document complements the initial work of D9.1 capturing the work regarding the shaping of the evaluation methodology definition for the six cMDFs (collaborative Manufacturing Demonstration Facilities), namely, the validation and feedback to the developers for incremental improvement, the measurement of the usability and the reporting of results following a common evaluation framework. |

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# Executive Summary

The deliverable D9.2 is the result of the work regarding the continuation of the evaluation methodology definition for the six cMDFs (collaborative Manufacturing Demonstration Facilities) amply described in D9.1.

WP9 "Validation, Demonstration and Evaluation of the iPRODUCE Social Manufacturing Space", defines the evaluation methodology along with the components to be used in the Open Innovation Space (OpIS) and the evaluation activities to be carried out at each of the six cMDFs for the OpIS validation.

Within WP9 the core functionalities and co-creation tools of OpIS will be validated demonstrating the value of the platform for the cMDFs assessing the impact of the iPRODUCE Social Manufacturing Framework.

In addition to the validation of the OpIS tools and services against the use cases, a comparable approach but at local and network level will be observed.

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# List of Abbreviations & Definitions

| Abbreviation | Definition |
|---|---|
| AR / VR | Augmented Reality / Virtual Reality |
| cMDF | collaborative Manufacturing Demonstration Facility |
| KPI | Key Performance Indicator |
| MMC | Maker, Manufacturer, Consumer |
| OpIS | Open Innovation Space |
| SME | Small and Medium Enterprise |
| SMS | Social Manufacturing Space |
| UC | Use Case |
| UX | User Experience |

# 1. Introduction

WP9 is focused on the validation, demonstration, and evaluation of the iPRODUCE Social Manufacturing Space and how to apply it to the different cMDFs, the physical spaces acting as local interfaces of manufacturing companies, from each of the different countries, reporting later the results of the analysis. Figure 1 shows the list of all use cases (UCs) in the six cMDF along with their title, country of origin and the prototype to be validated. A prototype in iPRODUCE is a product or a service to be validated within a use case.

| Country | cMDF | UC# | "Prototype" for validation |
|---|---|---|---|
|  | Collaborative Engineering in Customer-Driven Home Furnishing Products | 1 | Inteligent Headboard |
| | | 2 | Smart adjustable Gamer chair |
| | | 3 | 3D printed components for assembling customized furniture |
|  | Open Consultation, Collaborative Product Development, Collaborative Learning | 1 | CoCreation – Introduction for SME's |
| | | 2 | Machinery Training |
| | | 3 | Guided Product Development as a Service (GPDaaS) |
| | | 4 | MSB IoT Education Kit |
|  | Establishment of cMDF in French industrial ecosystem for developing collaborative projects in the automotive/mobility area and associated consumer goods sectors | 1 | Prototyping equipment tutorials to train and involve fablab user |
| | | 2 | Entrepreneurs & SME support to develop new devices in mobility sector |
|  | Collaborative manufacturing environment with cross-competences sharing for product development/enhancement in the microelectronics consumer sector | 1 | Linear Translation Robo shaker |
| | | 2 | Distributed Watering System |
|  | Establishment of a mobile BetaFactory Unit | 1 | Co-creation in schools |
| | | 2 | Distributed Design Market |
| | | 3 | Temporary Architecture |
|  | Upgrade of the design of a 3D printed medical equipment including IoT sensors integration | 1 | IoT-based Orthopaedic back brace |
| | | 2 | Splints for fractures |
| | | 3 | Splints for pets |
| | | 4 | Customized face shields |
| | | 5 | 3D printed smart luminous artifacts |
| | | 6 | 3D printed (bio) scaffolds |

Figure 1 – iPRODUCE's list of prototypes for validation overview

D9.2 documents the second phase of the Evaluation Framework of the iPRODUCE Open Innovation Space (OpIS), the digital platform to be developed in iPRODUCE, in the scope of the Social Manufacturing Space (SMS), the ecosystem of interpersonal relationships.

## 1.1. Purpose and Scope

The objective of this deliverable is to continue with the evaluation methodology of the software components developed in the OpIS platform from a user point of view, based on the KPIs defined at D9.1 and thinking in the expectations from the user's point of view from each cMDF.

## 1.2. Relation to other iPRODUCE Work Packages and Tasks

This deliverable is framed within the "Validation, Demonstration and Evaluation Methodology, Plan and Metrics", Task 9.1. As Figure 2 shows, WP9 (Validation, Demonstration & Evaluation of the iPRODUCE Social Manufacturing Space) shares interactions with mostly all work packages in the project. WP9 is particularly linked to **WP2** (Business Challenge Definition for Social Manufacturing in Consumer Goods Sectors), since this WP will confirm the project vision and user scenarios aligning such vision with collaborative production models and technologies as well as providing the global requirements, KPIs and a framework illustrating the IPRODUCE Open Innovation Space.

In addition, WP9 is related to **WP3** (Establishment of Local Collaborative Manufacturing Demonstration Facilities (cMDFs) where the different local cMDFs are established and **WP4**

(iPRODUCE Core Services and Digital Platform for Social Manufacturing) where the core platform of tools and services will be developed.

Additional interconnections are established between WP9 and **WP5** (Customer-Driven Production and Co-Creation Enabling Tools) since WP5 contains some of the components being evaluated such as the Generative Design Platform widely used during the idea generation process. WP9 is related to **WP6** (Social Media-Enriched Engagement Strategies for Makers and Consumer Communities) mainly with the mobile app to be used to assess the user's opinions and with **WP7** (iPRODUCE Sharing Economy Business Models and Execution Tools) because of the business models to be developed within each cMDF that will affect the use cases validation.

Finally, WP9 is related to **WP8** (iPRODUCE Integrated Social Manufacturing Space) because it addresses the Social Manufacturing Space (centerpiece for WP9 and later described in section 5) for acceptance testing of the whole iPRODUCE platform.

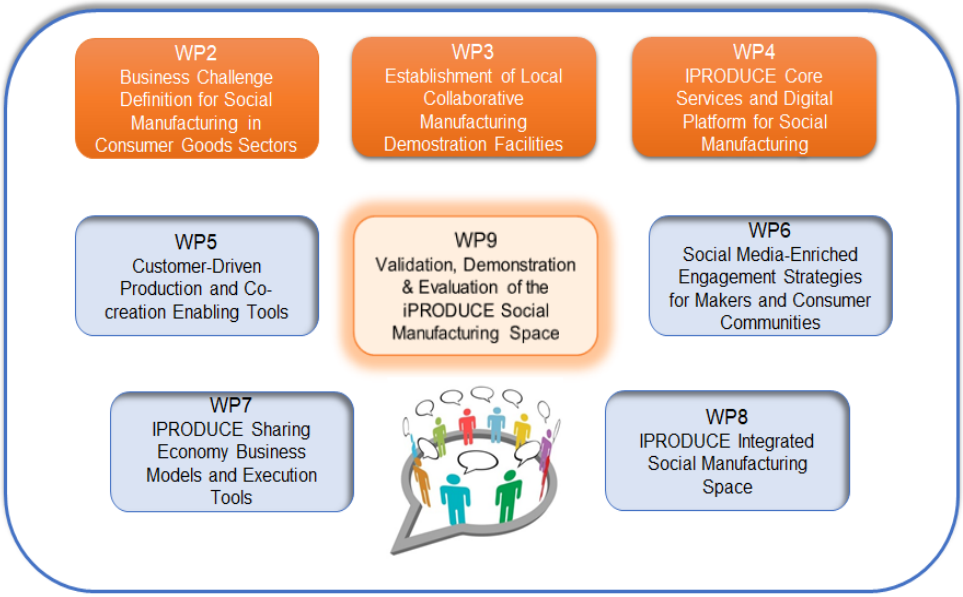


Figure 2 – WP9 relationship with the rest of WPs

## 1.3. Structure of the Document

The document is made up of nine sections. The first one is an introductory section where the document is explained as to its purpose, scope, relation with other work packages and structure. Section two offers an introduction to the overview of the validation activities carried out. Section three enters in the pilot evaluation with stakeholders defining a criteria with the pilots' involved stakeholders. Section four examines the project horizontal KPIs evaluation presenting these Indicators, their target values aiming to reach until the end of the iPRODUCE project at M36, and how these values will be calculated. Section five explores the usability analysis per component. Here, a thorough approach is done. First, recalling the Evaluation Framework established in D9.1 which is the basis of the evaluation activities to perform an analysis of the tools´ usability evaluation, a user satisfaction and user experience and socio economic assessment in the rest of WP9 tasks. Section six establishes the cMDF specific KPIs evaluation introducing the concepts of Midterm Evaluation and Final Evaluation and describing how the cMDF will undergo the evaluation process. Section seven closes the validation activities addressing the technical validation of the iPRODUCE components, with emphasis on the

constraints and assumptions for the validation process, its approach and an assessment and feedback collection, introducing a template questionnaire that will be used to later gather the users' satisfaction.

Document closes with a next steps section, which will open the validation process on the D9.3, the evaluation report of the iPRODUCE digital platform, where the application of the evaluation methodology will be documented.

# 2. Overview of the Validation Activities

A multi-faceted validation methodology is proposed which aims to collect feedback from all identified stakeholders with targeted activities at each project stage. The following table outlines the activities which will be analyzed in more detail in the subsequent paragraphs.

Table 1 - iPRODUCE Overview of Evaluation Activities

| Activity | Title | Evaluation Method | Stakeholders to be involved | Evaluation period |
|---|---|---|---|---|
| 1 (Section 3) | Pilot Evaluation with Stakeholders | Structured interviews Establish pilots requirements and evaluate the pilots with all stakeholders | directly involved stakeholders- cMDFs, makers and customers | Before pilot development / After pilot execution |
| 2 (Section 4) | Project Horizontal KPIs evaluation | Horizontal KPIs defined In D9.1 Evaluation by gathering and reporting values during pilots | directly involved cMDFs | Evaluation at the end of the project |
| 3 (Section 5) | OpIS Value Proposition | Standard UEQ, User Experience and Socio-Economic Assessment | directly involved stakeholders-cMDFs, makers and customers | At the middle of the pilot, Midterm (feedback to developers) M27 and at the end of the pilots execution M36 |
| 4 (Section 6) | cMDF specific KPIS evaluation | Method defined in each KPI per use case in D9.1 | directly involved cMDFs | At the middle of the pilot, Midterm (feedback to developers) M27 and at the end of the pilots execution M36 |
| 5 (Section 7) | Technical Validation of Components | Adopted standard | directly involved cMDFs | At the middle of the pilot, Midterm (feedback to developers) M27 and at the end of the pilots execution M36 |

# 3. Pilot Evaluation with Stakeholders

Due to the diverse aspect of the pilots, the successful criteria need to be co-defined with the pilots' involved stakeholders.

The evaluation needs to be divided in two rounds, one before the start and another one after the end of the pilot period. In the first round, based on the pre-defined criteria, both the cMDFs and the stakeholders will identify what needs to be evaluated by filling out an online form or through an interview (mode to be chosen by each cMDF to best fit with local practices). In the second round the cMDF and stakeholders will revisit the criteria and evaluate them based on the pilot experience. CBS will prepare the evaluation questionnaire, while the cMDFs will support the process by translating the material to their local language, and making personal requests to the stakeholders to fill out the form, which should be translated back to English and returned to CBS within the defined timeframe.

The reason for having both stakeholders and cMDFs fill out the questionnaire is to ensure that both parties might have distinct goals, expectations and experiences from the pilots and all of these must be taken into account.

In order to fulfil the evaluation process the pilots and the stakeholders involved need to define the criteria following the structure presented on Table 2.

Table 2 - Criteria to be defined by both stakeholders and cMDFs before running the Pilot.

| Criteria name | What to be evaluated |
|---|---|
| Goal | The key goal (design and prototype a new chair, design a produce a new solution for x, locally produce furniture, facilitate access to digital fabrication, test parametric design solutions, design and produce new medical gear, etc. |
| Expectation | The key expectation<br>(explore digital fabrication for new products, facilitate prototype creation, accelerate production, accelerate testing new ideas, learn about digital fabrication, etc.) |
| Process | The process format<br>(co-creation workshops, meetings, production, review, follow-up, etc.) |
| Technical aspects | The technical aspects to be evaluated (capability, performance, results, experience, etc.) |
| iPRODUCE platform | The tools to be used through the platform<br>(AR/VR, Matchmaking, etc.) |
| iPRODUCE platform experience | The key aspects to be assessed (design, usability, accessibility, value) |
| iPRODUCE platform value | The overall value of the platform for future cases |
| Pilot Value | The overall pilot experience |
| Technology value | The value of the technology in regards to the goal of the pilot |
| TBD according to stakeholder request | TBD |

In the second round of the evaluation, the cMDFs and stakeholders need to revisit the initially set criteria and evaluate them accordingly as suggested on Table 3.

Table 3 - Criteria to be evaluated by both stakeholders and cMDFs after running the Pilot.

| Criteria Name | What to be evaluated | How to be evaluated | Tool |
|---|---|---|---|
| Goal | The key goal (design and prototype a new chair, design a produce a new solution for x, locally produce furniture, facilitate access to digital fabrication, test parametric design solutions, design and produce new medical gear, etc. | Achieved/not achieved | Online questionnaire/ interview |
| Expectation | The key expectation (explore digital fabrication for new products, facilitate prototype creation, accelerate production, accelerate testing new ideas, learn about digital fabrication, etc.) | fulfilled/not fulfilled | Online questionnaire/ interview |
| Process | The process format (co-creation workshops, meetings, production, review, follow-up, etc.) | Structured/not structured | Online questionnaire/ interview |
| Technical aspects | The technical aspects to be evaluated (capability, performance, results, experience, etc.) | Rate 1-5 | Online questionnaire/ interview |
| iPRODUCE platform | The tools to be used through the platform (AR/VR, Matchmaking, etc.) | Rate 1-5 | Online questionnaire/ interview |
| iPRODUCE platform experience | The key aspects to be assessed (design, usability, accessibility, value) | Rate 1-5 | Online questionnaire/ interview |
| iPRODUCE platform value | The overall value of the platform for future cases | Rate 1-5 | Online questionnaire/ interview |
| Pilot Value | The overall pilot experience | Rate 1-5 | Online questionnaire/ interview |
| Technology value | The value of the technology in regards to the goal of the pilot | Rate 1-5 | |
| TBD according to stakeholder request | TBD | | |

# 4. Project Horizontal KPIs Evaluation

This section presents the Key Performance Indicators (KPIs), the target values aiming to reach until the end of the iPRODUCE project at M36, and how each pilot will calculate these values. Particularly, these KPIs will be measured based on OpIS Platform digital tools, in order to evaluate and assess the efficiency of the results of the project.

Table 4 - Project Horizontal KPIs

| Code | Indicator | Target value at M36 | How will be calculated |
|---|---|---|---|
| KPI-3 | Number of MMC communities developed | 1 per pilot area | By using the **Matchmaking & Agile Network Tool** and the **Marketplace** |
| KPI-4 | Number of manufacturing SMEs involved in the collaborative manufacturing processes of the MMC communities | >120 (or 20 per pilot area) | By using the **Matchmaking & Agile Network Tool,** the **Marketplace** and the **Ricardian Toolkit** |
| KPI-5 | Number of engaged makers and consumers in the collaborative manufacturing processes of the MMC communities | > 1200 (or 200 per pilot area) | By using the **Matchmaking & Agile Network Tool** and the **Marketplace** |
| KPI-6 | Participants in the pilot activities | >600 (or 100 per pilot area) | By using the **Matchmaking & Agile Network Tool** and the **Marketplace** |
| KPI-7 | Local cMDFs developed | 6 (1 per pilot area) | By using the **Marketplace** |
| KPI-11 | Open innovation missions where collaborative manufacturing will be applied | 15 missions | By using the **Mobile App** |
| KPI-12 | Customer-driven products manufactured in cMDFs | >12 (2 per pilot area) | By using the **Matchmaking & Agile Network Tool,** the **Marketplace,** the **Generative Design Platform** and the **VR/AR Toolkit** |
| KPI-13 | Collaborative manufacturing business cases/model | >12 (2 per pilot area) | By using the **Matchmaking & Agile Network Tool** |
| KPI-14 | Improvement in the perceived ability of manufacturing SMEs to apply open innovation methods | >20% increase | By using the **Mobile App** |
| KPI-15 | Improvement in makers' and consumers' perceived readiness to participate in collaborative manufacturing | >20% increase | By using the **Matchmaking & Agile Network Tool** |
| KPI-17 | Demand-driven sharing economy business model | 6-12 (1-2 per pilot) | By using the **Ricardian Toolkit** |
| KPI-18 | Validated, market ready (business models and plans) products | 6-12 (1-2 per pilot) | By using the **Marketplace** and the **Mobile App** |
| KPI-19 | Size of sharing economy developed | >3000 participants (>500/city; measured as no of people using our digital platform and block chain mechanisms to exchange knowledge, services and products) | By using the **Ricardian Toolkit** and the **Marketplace** |

| | | | |
|---|---|---|---|
| KPI-20 | Community members as beneficiaries of entrepreneurship training | > 300 (50 per pilot) | By using the **Digital Fablab Kit** |
| KPI-27 | Makers and consumers involved in the co-design of products | > 120 (20 per pilot) | By using the **Matchmaking & Agile Network Tool,** the **Marketplace** and the **VR/AR Toolkit** |
| KPI-30 | Reduction in the development cost for new product | >20% (as reported by participating SMEs) | By using the **Generative Design Platform,** the **VR/AR Toolkit,** and the **Matchmaking & Agile Network Tool** |
| KPI-31 | Customer-driven products manufactured in cMDFs | >12 (2 per pilot area) | By using the **Matchmaking & Agile Network Tool,** the **Marketplace** the **Generative Design Platform** and the **VR/AR Toolkit** |
| KPI-34 | Number of engaged makers and consumers in the collaborative manufacturing processes of the MMC communities | > 1200 (200 per pilot area) | By using the **Matchmaking & Agile Network Tool,** the **Marketplace,** the **Generative Design Platform** and the **VR/AR Toolkit** |
| KPI-36 | Consumers' satisfaction with regards to the co-manufactured products | > 90% | By using the **Mobile App** |
| KPI-37 | Consumers' willingness to support the manufactured products (loyalty) | > 70% (among the communities' and pilot participants) | By using the **Mobile App** |
| KPI-38 | Manufacturers, makers and consumers in the needs analysis | >3000 (>500 per pilot) | By using the **Marketplace, Matchmaking & Agile Network Tool,** and the **Mobile App** |

The KPIs mentioned in the above table are going to be achieved using the digital components of the OpIS platform. Each tool aims to fulfill a set of related KPIs. For example, the **Matchmaking & Agile Network Creation tool** can increase the number of MMC communities and the involved users that participate in the collaborative manufacturing processes. The **Marketplace** is used as a way to introduce new users and products to the OpIS platform and the available digital tools. The **Ricardian toolkit** is responsible for validating the business models and the shared economy developed within the scope of the project in a secure way. The **VR/AR Toolkit** and the **Generative Design Platform** aim to increase the number of customer driven products created and validated through intuitive and novel techniques.

Data from all the digital tools related to users and products are stored on the central OpIS data Repository. By directly measuring the data derived from the software components, we can calculate the achievement of the targeted KPI values. All those data come from every pilot site and cMDF using the platform's components hence the Horizontal functionality evaluation.

KPIs that are related to user satisfaction can be measured based on the questionnaires that will be filled by the MMCs.

More specifically, most of the values that appear on the above table aim to increase the number of participants (manufacturers, makers and consumers) in the collaborative manufacturing processes on the pilot sites and engage them in social activities. The Matchmaking & Agile Network Tool will

implement an extensive data mining process and data mining techniques in order to properly describe the profile of involved stakeholders. This way it will allow the OpIS platform users to find the most suitable partners, products and services to enable the development of agile collaboration networks, increasing the number and size of the established communities by bringing the right people together. In addition, the Marketplace by providing the ability to register new users (makers, communities, consumers) where each can create their own profile and publish their list of ideas and products offers a direct way to increase and measure the number of participants in the pilot activities.

The Generative Design platform and the VR/AR Toolkit will address KPIs related to the customer driven products and the reduction of production costs. The collaborative development of a new product using traditional manufacturing processes is usually a timely and costly procedure, as multiple stakeholders have to engage in back and forth conversations about details, specifications and modifications. Using a combination of the above novel digital tools this procedure can be greatly simplified as designers can prototype their ideas quickly and efficiently through the Generative Design Platform and share them with the involved stakeholders in real time through the VR/AR Toolkit in order to receive and implement feedback. This virtual collaborative prototyping method can significantly accelerate the pipeline between the conceptual phase of a product and its materialization thus reducing the related cost while allowing an increased number of such product ideas to come into fruition.

The mobile application aims to obtain Voice of Customer feedback through which iPRODUCE can actively obtain input about Consumer satisfaction, evaluation of the developed products and willingness to participate in collaborative activities. Using questionnaires and surveys conducted through the app the related KPIs can be directly addressed.

Finally, the Ricardian Toolkit will define the transaction management strategies that can be applied to facilitate the formation and operation of multi-party stakeholder teams, which will engage in the collaborative manufacturing activities. Through recording documents as contractually lawful, and then securely linking them in order to serve as an issuance of value it aims to attract more stakeholders to use the platform and its block chain mechanisms to exchange knowledge, services and products. The size of the shared economy that will be developed based on that concept can be significantly increased and measured through the digitization of the collaboration contracts through secure block chain and cryptography technology that eliminates frauds.

# 5. OpIS Value Proposition

## 5.1. Evaluation Framework

The iPRODUCE evaluation framework has been set up to allow the evaluation of the outcomes of the project from the end users' point of view and experience. After all, the concept of the iPRODUCE project puts the users in the center of the development, the evaluation of performance and the satisfaction.

The usability evaluation in iPRODUCE will reveal the overall acceptance and usability of iPRODUCE Social Manufacturing Framework from the point of view of all involved stakeholders.

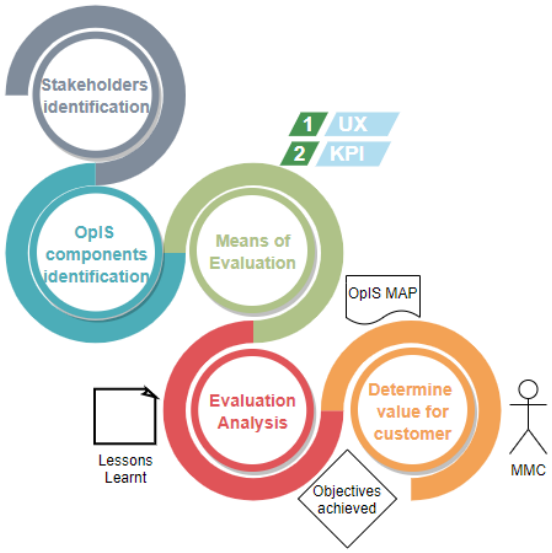


Figure 3 - iPRODUCE Evaluation Methodology

D9.1 presented the evaluation methodology focusing on the KPIs that are used to define the end users' (cMDFs') expectations for the OpIS tools. This section of the evaluation framework is to build upon that, covering the methodology to assess the suitability of a tool for a specific use case and the user satisfaction, which it entails. By these means, the value of any iPRODUCE tool for the cMDF as end users as well as the value of the cMDFs for their MMCs can be determined.

The evaluation approach is based on a combination of indicators assessing satisfaction, user experience (UX), human needs, and attitudes towards innovation (makers) and consumption (consumers).

The evaluation and assessment within iPRODUCE follows the human-centered design (HCD) approach (see Figure 4) according to the ISO 9241-210 standard (ISO 2019). In this way, all the different actors who are involved in each use case are to be included. These stakeholders are part of the MMC of each cMDF and assume different roles regarding the OpIS components in use. After the identification of stakeholders and the components they interact with, the value of these tools and of the pilots for the involved actors is to be determined. Whereas the KPIs as the first means of evaluation provide concrete, *objective* measures for the level of satisfaction of the stakeholder needs (covered in D9.1), questionnaires provide a more *subjective*, albeit quantitative, metric that takes into account the actors' personal evaluation in line with the HCD approach. The idea is to make the OpIS components

as well as the pilots' use cases more usable by gathering and later addressing user feedback derived from their use of these interactive systems.

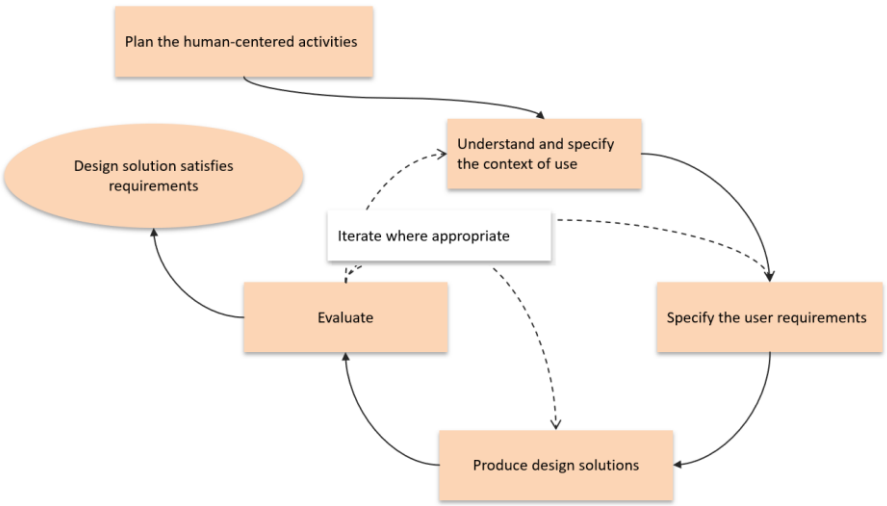


Figure 4 - Interdependencies of human-centered design activities [DIN ISO 9241-210:2010]

## 5.2. Usability Evaluation

Whereas the pilot evaluations and socio-economic assessment in Task 9.6 focuses more on the impact of pilots and the iPRODUCE Social Manufacturing Framework for innovation as well as on user and customer experience (covered below), the validation of the iPRODUCE platform in Task 9.2 puts emphasis on the usability of the tools that is their effective, efficient, and satisfying support for the user's task. The international norm ISO 9241-11 (ISO, 2018) specifies the quality construct of usability as a three-stage ladder (see Figure 5).

At the lowest level – the "effectiveness level" – the system must provide all the information and functions required by the work task that a user needs to be able to perform his work effectively.

At the second level – the "efficiency level" – it is not only important that all information and functions are available, but that they can be found or operated without unnecessary effort. Therefore, according to ISO 9241-110 (ISO, 2020), the tool must be suitable for the user's task, self-descriptive, controllable (including individualized), use-error robust, learnable, conform to expectations, and engaging. Particularly important is the fit of the tool to the typical, "informal task completion" of the users.

At the top level – the "satisfaction level" – the user's physical, cognitive, and emotional responses that result from using the tool should meet the user's needs and expectations. Optimally, users should have a positive attitude towards using the tool resulting from an achievement of all task objectives without negative influences or risks.

In this way, user satisfaction extends the usability aspects of effectiveness and efficiency with the immediate UX, focusing on the experiences that result from expectations and risk mitigations. According to ISO 9241-210 (ISO 2019), the construct of UX encompasses all user perception and responses resulting from use or anticipated use. Questionnaires focusing on pragmatic and emotional aspects are the common methodology to assess the satisfaction during or after use. Since the iPRODUCE Digital platform is a work tool, the UX is significantly influenced by the quality of usability. Accordingly, the UX can for the most part be construed based on the three levels.

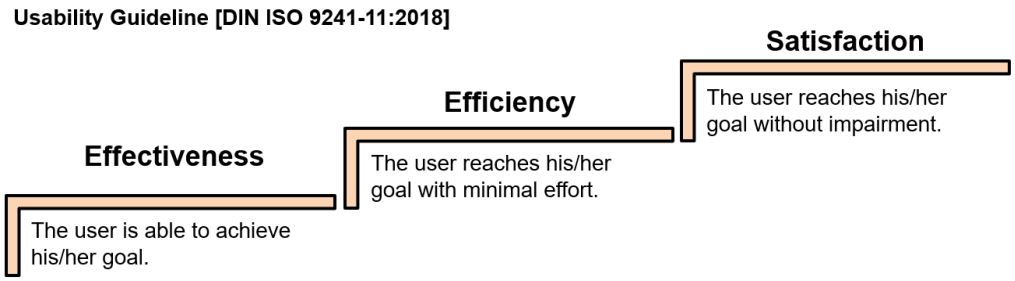


Figure 5 - Three-stage usability quality ladder [DIN ISO 9241-11:2018

User testing and expert walkthroughs are methods from usability engineering to determine both the effectiveness and the efficiency of a system regarding its support for task achievement. In line with Nielsen (1993), at least five test users should be employed to find most usability problems through user tests. A more cost-effective method is the expert walkthrough or scenario-based walkthrough, in which a system is inspected by usability experts who take on the role of users working on typical tasks with the evaluated tool. With a large-enough number of test users, questionnaires can be applied in order to cover the third usability level satisfaction and more task-independent UX aspects.

## 5.3. User Satisfaction Assessment

Standardized questionnaires are suitable to cover the prevalent UX aspects as the basis for a user satisfaction assessment. Together with the KPIs as defined in D9.1, they represent the means of evaluation of the OpIS components.

The User Experience Questionnaire (UEQ, Schrepp, 2015) is a common tool used to capture both classic usability aspects (pragmatic quality) and more hedonic, experiential aspects. According to Hassenzahl (2003), there are two basic quality dimensions: pragmatic and hedonic quality. Whereas the pragmatic quality refers mostly to usability and the prevention of problems and negative experiences, hedonic quality is non-instrumental and concerns positive emotions and the fulfillment of psychological needs like stimulation and novelty. This distinction is prevalent in UX research and accordingly, the UEQ scales include:

- Attractiveness: Overall impression of the product. Do users like or dislike it?
- Perspicuity: Is it easy to get familiar with the product and to learn how to use it?
- Efficiency: Can users solve their tasks without unnecessary effort? Does it react fast?
- Dependability: Does the user feel in control of the interaction? Is it secure and predictable?
- Stimulation: Is it exciting and motivating to use the product? Is it fun to use?
- Novelty: Is the design of the product creative? Does it catch the interest of users?

Source: https://www.ueq-online.org

In this way, the UEQ is suitable to be used for the general satisfaction assessment and thus provides a basis for measuring the general user experience and quality perceptions of the components, both from a pragmatic (perspicuity, efficiency, dependability) and an emotional (attractiveness) or hedonic (stimulation, novelty) perspective. In this way, the UEQ takes a variety of user needs into account.

Combined with the questionnaires, there is an opportunity to run interviews with some of the partners involved in the use cases (3 interviews per cMDF). The reason for that is that interviews, as a qualitative research approach, provide more elaborated insights regarding user interactions and

perspectives or the "ability to penetrate the experiential social worlds of intentional, self-directing actors, whether through the spoken or written word" (MANGEN, 1999, p. 110).

## 5.4. User Experience and Socio-Economic Assessment

Based on the evaluation of the OpIS tools, furthermore, the overall value for the MMCs and customers as the socio-economic impact will be assessed. For the development of interactive systems that are suitable not just for the user's task but also for a risk-free, meaningful work and human life, also basic psychological needs and possible user stresses must be considered. In the context of MMCs and need for innovation as well as for confidence in their capabilities as makers, the three basic psychological needs derived from self-determination theory (SDT, Edward L. Deci & Ryan, 1985; Ryan & Deci, 2017) are of special importance and are subject to evaluation: autonomy, competence, and relatedness. Autonomy concerns volitional and self-endorsed behavior, competence effectively interacting with and influencing one's environment, and relatedness the closeness to and the care by others (Vansteenkiste & Ryan, 2013).

The application of SDT's three human needs to HCI was originally conceptualized and demonstrated by the Positive Computing approach (Calvo & Peters, 2014; Peters et al., 2018), which puts emphasis on the importance of basic human need support as a means to create a more positive, engaging, meaningful, and psychologically healthy UX. These three needs are of special importance for the concept of makerspaces and innovation as in this context, users as human beings work collaboratively and employ creativity and self-determined activities in order to invent and produce within their MMCs. Contrasting the active support of autonomy, competence, and relatedness through the iPRODUCE tools and use cases, basic psychological needs can also be actively thwarted by the individual's environment. Translated to interactive technology, this means that potentially need-thwarting tools in use might cause psychological need frustration in the user, which has been shown to lead to various negative outcomes, such as stress, anxiety, depression, reduced self-control as well as defiant and immoral behavior (Vansteenkiste & Ryan, 2013). Therefore, it stands to reason to evaluate the cMDFs' tools, methods, products, and services for MMCs regarding their potential to both support and thwart basic psychological needs in order to design and create technology that is not only suitable for users but suitable for humans.

Thus, on the one hand, makers' and customers' autonomy in creating and using the OpIS tools and iPRODUCE solutions must not be thwarted and optimally, be supported to add to a self-determined working environment. Otherwise, users would feel controlled and patronized during use. Next, users of those tools should feel competent and optimally challenged when dealing with the tools in order to increase their confidence and self-efficacy as makers and stay engaged in their innovation processes. The avertable alternative would be perceptions of chaos, a dearth of accomplishments and feelings of incompetence and frustration. Third, makers' needs for relatedness with their MMC must be satisfied in line with the collaborative nature of the maker enterprise in general. Otherwise, makers would experience neglect, isolation, and disconnection from their community. Thus, a questionnaire adapted from the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) to fit the technological environment that iPRODUCE represents will be applied to examine the use cases' potential supporting or thwarting effects on stakeholders' autonomy, competence, and relatedness.

In line with research in UX and work psychology, these human needs are linked to stress responses when frustrated and positive psychological development and work outcomes like engagement when satisfied. Building upon the UX and human need assessment, another section of the questionnaire will cover the pilots' perceived impact on CMM's work in the form of value creation, performance, and feasibility along with attitudes towards innovation and engagement in Industry 4.0 activities. The aim is to understand the impact of the iPRODUCE Social Manufacturing Framework, delivered by the pilot cMDFs through the iPRODUCE platform to their MMCs, on both maker/manufacturer behavior and consumer profiles in line with the HCD approach, which takes all relevant stakeholders into

consideration. Moreover, these work and consumption outcomes can be examined for their connection with the perceptions of the solutions' UX and potential need for support/thwarting. Specifically, these considered outcomes are as follows: First, makers' and manufacturers' orientation towards innovation are key indicators of the projects' capacities to enhance and transform MMCs all around Europe. Second, maker and manufacturing capabilities and confidence concern the impact on the actors' self-assessment in their role of creating and producing. Third, consumers' purchasing attitudes with regard to iPRODUCE's move towards digital tools and Industry 4.0 are to indicate new consumer profiles as well as the (after-sales) purchasing possibilities that they entail.

Moreover, a general section of the survey will poll gender and demographic data. On that basis, analyses can determine whether the experience of using the OpIS tools is related to the sample's features. Finally, the assessed tools and use cases need to be judged by the survey participants regarding their importance for and influence on their experimentation in their MMC.

All the mentioned-above will be useful to consider the further implementation of the iPRODUCE framework in more companies and networks at an EU level. As an iterative process, these HCD activities will inform the further development of the systems and services of the iPRODUCE pilots' use cases and prospectively, of all European MMCs and their activities.

The questionnaires for the pilot evaluation will be distributed via an online survey tool among all the stakeholders as defined in the descriptions of the cMDFs' use cases. In the case of user testing, satisfaction questionnaires can possibly be given directly to the test users

# 6. cMDF Specific KPIs Evaluation

D9.1 established the overall Evaluation Methodology for the assessment of the software components developed in the OpIS platform from a user's point of view, based on the KPIs defined for each cMDF. Such methodology will be put into practice to validate the technological solutions developed within the iPRODUCE project giving proper feedback to the technical developers for continuous enhancement.

Two iterations of the iPRODUCE evaluation are intended. The first one, the **Midterm Evaluation** will cover everything until **month 27** (March 2022), whereas the final one, **Final Evaluation** will account at **month 33** (September 2022), hence reporting the last six months since the Midterm. Both evaluations will be documented under D9.3, the Evaluation Report of iPRODUCE Digital Platform.

Figure 6 shows all the different entities that take part in the Evaluation of the iPRODUCE OpIS platform. On one side, the different stakeholders represented under the MMC communities along with the six project established cMDFs. Each of these cMDFs has produced a well defined set of use cases that will prove the suitability of the different tools in the OpIS platform through the KPIs defined within. In addition to the KPIs, there are two other means of evaluation as stated in D9.1, namely questionnaires and interviews.

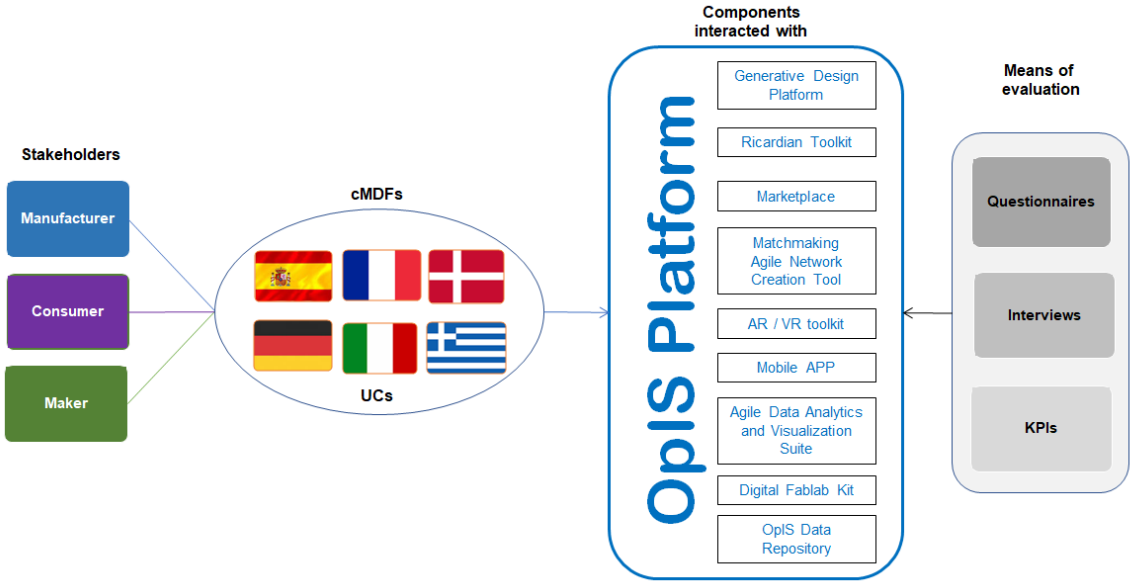


Figure 6 - Overall view of the iPRODUCE OpIS Platform Evaluation.

Getting deeper in the relationships of the different entities, Figure 7 depicts a flow approach relationship. The stakeholders identified as the makers, consumers and manufacturers are part of the iPRODUCE community, and are the ones interacting with each of the OpIS components used within the scope of each use case defined at the cMDF level. Stakeholders will serve as evaluators and will have the final word whether a component is suitable or not through the different means of evaluation mentioned above. This cycle will continue until all KPIs have returned a final result and all the questionnaires and interviews have been administered. Then, proper feedback will be given to the technical providers for future enhancements of the final solution. All this process will happen twice, once in the Midterm Evaluation and continuing until the Final Evaluation.

Midterm Evaluation is an intermediate stage whose main objective is to "measure the project's temperature" and most importantly, get the stakeholders involved with the OpIS tools so they can get

acquainted with the components in a preliminary testing while at the same time, offering valuable input to the developers.

Final evaluation will lastly determine if the components were suitable. First, if the KPI or KPIs that were involved in, threw a positive value, that is, if the TO-BE value specified in the use case tables of D9.1 was achieved or even exceeded. And then, the defined questionnaires and/or interviews that were administered to the different stakeholders had at least a passing score. This last method comprehended within the means of evaluation listed in D9.1 is completely subjective since it deals with the usability or satisfaction level of the user and the tool, whereas the KPI, the other means of evaluation method, will yield an objective value throwing a definite assessment of whether the component satisfied the use case KPI or not.

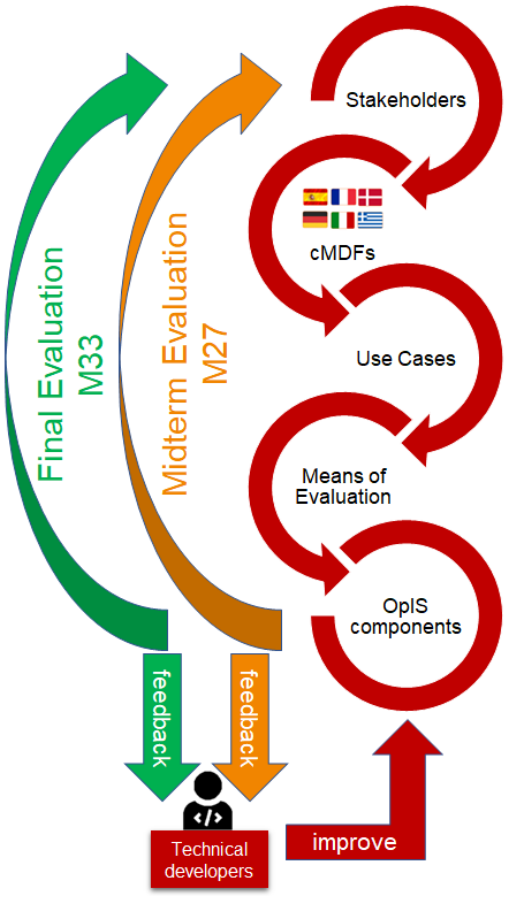


Figure 7 – iPRODUCE Evaluation Flow

The application of the iPRODUCE Evaluation Methodology will produce a set of lessons learnt that could potentially spawn fresh ideas for new developments or simply enhancements on the already existing components.

Summarizing, this evaluation will assess primarily the suitability of a component in the use case that is used at. Further analysis will determine if this specific component has a value for the customer as well. The results methodology application will be reported in D9.3, therefore the iPRODUCE methodology has to consider the application, analysis and consequently, final value for the stakeholder.

# 7. Technical Validation of Components

## 7.1. Constraints and assumptions for the validation

- This validation was designed to be applicable to distinct components.
- The components will be thoroughly tested by end-users during the pilot execution. They will be instructed to use the generic functionalities so that they can assess them.
- This evaluation is focusing on qualitative assessment .
- Scenario-based validation approach will be followed..
- If a scenario is covered by a combination of different tests, then the scenario is assumed to be validated as a whole.
- End-users are assumed/planned to have appropriate training at the pilot sites, and therefore will be able to execute the tasks with similar efficiency and ease that is demonstrated.

## 7.2. Validation Approach

This methodology was designed following a review of the available quality and validation models and has adopted and adapted them to fit the purpose of the specific validation with the assumptions mentioned above. ISO/IEC 25010 [12] defines the product quality model shown in Figure 8 below, while scenario-based testing covers the Functional Suitability and Performance Efficiency characteristics, according to ISO/IEC 29119-4 [13]. The technical validation of the components follows quality characteristics, to the degree possible and taking into account the conditions of the validation procedure. This means that we cannot consider the entire product quality model (as shown in the Figure below) when we are working in a low TRL project. A subset of those validation domains (qualities) have been adapted as explained below to fit the task and support the validation procedure in a simplified manner which is focused on component validation. The usability evaluation was not considered as this was covered by the UEQ (see section 4).

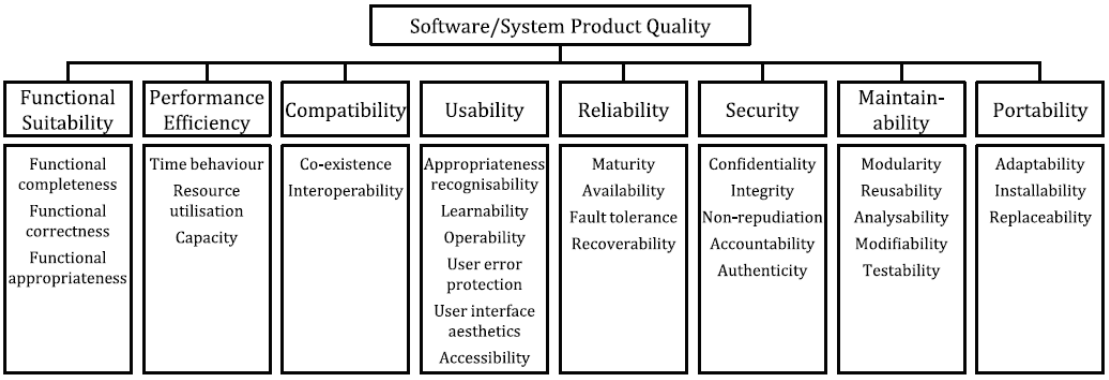


Figure 8 - ISO/IEC 25010 product quality model[1]

Criteria from standards and de facto validation methodologies have been followed. The validation at this stage is qualitative; nevertheless appropriate metrics should be selected in order to derive usable results. A number of selections was made top-down (from non-measurable qualities to measurable attributes), in order to decide on which metrics will be used. This process is described below:

[1] https://iso25000.com/index.php/en/iso-25000-standards/iso-25010?start=6

### 7.2.1. Characteristics and attributes selected

The **following** characteristics of the afore-mentioned qualities are **selected** for the components' validation[2]. Each characteristic has measurable attributes[3]. The attributes that were selected and evaluated as possible to be assessed in the context of this validation are :

- **Functional suitability**
  - **Functional completeness**: Degree to which the system functionalities cover the functionalities that the user expects
  - **Functional Correctness:** what proportion of the task is achieved correctly?
  - **Functional appropriateness**: - Degree to which the system functions are appropriate for the task accomplishment
- **Performance Efficiency**: *Task performance* - Degree to which the task is performing or functioning in the best possible manner with the least waste of time and effort by using the component. Frequency of errors? How efficient are the users?
- **Compatibility**: Degree to which the component performs well in this entire OPIS without detrimental impact on any other component.
  - **Interoperability**: Degree to the component exchanges and uses information with other components within OPIS.
- **Reliability**: *Degree to which a component is reliable.*
  - **Maturity:** Degree to which the component meets the needs for reliability.
  - **Fault tolerance:** Degree to which a component operates well despite the present of faults.
- **Portability**: *Degree to which a component can be effectively used in different usage environments.*

**Adaptability:** Degree to which the component can be effectively adopted in different or evolving usage scenarios.

The derivation of these specific metrics out of the selected qualities is summarized in the table below:

Table 5 - Summary of derived metrics

| Quality | Characteristic | Attribute / Metric |
|---|---|---|
| Functional suitability | Functional completeness | Concept completeness |
| | Functional correctness | Proportion of task achieved correctly |
| | Functional appropriateness | Functional adequacy |
| Performance Efficiency | Efficiency | Task performance |
| Compatibility | Interoperability | Degree of exchanges with other components |
| Reliability | Maturity | Reliability needs covered |
| | Fault Tolerance | Degree of good operation |
| Portability | Adaptability | Effective adoption to other usage scenarios. |

[2] Selected characteristics for validation will be re-assessed in the follow-up validations (integrated system, open calls), to meet the objectives and focus of each validation activity.
[3] Some of the characteristics selected below, may partially overlap with the Usability Evaluation as described in the previous Chapter, since Product Quality is linked to user satisfaction. The implementation of our methodology will exclude such overlaps.

## 7.3. Assessment and feedback collection

Structured questionnaires were derived for the end-users to validate the components. A validation methodology for scenario-based testing [18] has been tailored and adapted, to consider the additional constraints and the assumptions defined. Questionnaires are answered for each component (one questionnaire per component).

The attributes are assessed qualitatively using a five-level scale from 1 (Completely disagree) to 5 (Completely agree). For a more efficient validation procedure two sub-questions of free text are also included referring to functionalities of completeness and adequacy.

Attributes are assessed through the following questions[4]:

- **Functional completeness:**
  - 1a. The functionalities of the component cover my expectations for this task.
  - 1b.Please refer to the functionalities that don't totally cover your expectations.
- Functional correctness: Please evaluate the proportion of the task achieved correctly.
- **Functional appropriateness:**
  - 2a. The functionalities of the component are adequate for the accomplishment of this task.
  - 2b. Please refer to the functionalities that seem not to be adequate for the accomplishment of this task.
  - 3. The functionalities of the component facilitate the accomplishment of this task.
- **Task Efficiency:**
  - 4. Estimated percentage of good functioning of the task.
- **Compatibility:**
  - 5. Estimate the percentage of component exchanges with other components.
- **Reliability :**
  - 6a. Estimated percentage of satisfaction of the reliability needs
  - 6b. Estimate the degree of good operation despite the presence of faults.
- **Portability:**
  - 7. Estimated the potential of the component to be used in difference usage scenarios.

### 7.3.1. Compilation of questionnaire

The Questionnaire which has been compiled to assess the above-mentioned attributes and destined to be answered by each pilot end user for each component is the following:

[4] The questions are derived from the respective attribute's description

1. a. The functionalities of the component cover my expectations for this task.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Completely disagree | Disagree | Normal | Agree | Completely agree |

b. Please refer the functionalities that don't totally cover your expectations:

2. a. The functionalities of the component seem to be adequate for the accomplishment of this task.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Completely disagree | Disagree | Normal | Agree | Completely agree |

b. Please refer the functionalities that seem not to be adequate for the accomplishment of this task:

3. The functionalities of the component facilitate the accomplishment of this task.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Completely disagree | Disagree | Normal | Agree | Completely agree |

4. Estimated percentage of good functioning of the task.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| <25% Very Bad | Up to 25% Bad | Up to 50% Average | Up to 75% Good | Up to 100% Excellent |

5. Estimated percentage of component exchanges (what is visible to the user).

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| <25% Very Bad | Up to 25% Bad | Up to 50% Average | Up to 75% Good | Up to 100% Excellent |

6. a. Estimated percentage of reliability satisfaction.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| <25% Very Bad | Up to 25% Bad | Up to 50% Average | Up to 75% Good | Up to 100% Excellent |

1. b. Estimated percentage of good operation despite presents of faults.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| <25% Very Bad | Up to 25% Bad | Up to 50% Average | Up to 75% Good | Up to 100% Excellent |

c. Please refer the main identified faults:

| |
|---|
| |

2. a. Estimated percentage of usages in different scenarios.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| <25% Very Bad | Up to 25% Bad | Up to 50% Average | Up to 75% Good | Up to 100% Excellent |

# 8. Next Steps

D9.1 and D9.2 captured the work regarding the shaping of the evaluation methodology definition for the six cMDFs (collaborative Manufacturing Demonstration Facilities), concretely, the execution of the validation and feedback to the developers for incremental improvement, the measurement of the usability and the reporting of results following a common evaluation framework.

These two documents can be regarded as the "official guide" to commence with the evaluation process whose main outcome will be recorded in D9.3 (M33) "Final Evaluation Report of the iPRODUCE digital platform" during next task T9.2 starting on July-21. This final evaluation deliverable will provide a wide-ranging testimony of the usability, effectiveness and consequently, user value of the OpIS digital platform, and overall of the iPRODUCE technological offer.

But WP9 endures with two other deliverables that close the work package.

First, D9.4 (M36), "iPRODUCE services pilots, OI Missions and Federated structure" which will concentrate the work done in three tasks according to the overall validation activities defined in this deliverable:

- T9.3 (iPRODUCE Innovation services to MMCs), supporting the evaluation process while enabling the implementation of the iPRODUCE pilots for a successful outcome of the demonstrations and at the same time, feedback received by the MMCs will be used to provide enhancements to the technical solutions.
- T9.4 (Realization of local cMDF Pilots and Open Innovation Missions), comparable to T9.3, but responsible for implementing the pilots with an emphasis on the execution of the OI missions.
- T9.5 (Demonstration of the Federated Network of cMDFs and Business Model Validation) which will take the work performed in T9.2 and elevate it to the network of local cMDFs' level that is, focusing on the validation at the federated level.

Lastly, D9.5, Evaluation and socio-economic impact assessment report of iPRODUCE) will concern the aforementioned pilots' evaluation and socio-economic assessment methodology as the overall value for the MMCs and customers.

# 9. References

Calvo, R. A., & Peters, D. (2014). Positive Computing: Technology for Well-Being and Human Potential. The MIT Press.

Deci, E. L [Edward L.], & Ryan, R. M [Richard. M.]. (1985). Intrinsic Motivation and Self-Determination in Human Behavior. Springer Science+Business Media.

Hassenzahl, M. (2003). The thing and I: understanding the relationship between user and product. In M. A. Blythe, Overbeeke, Kees., Monk, Andrew F., & P. C. Wright (Eds.), Funology: From Usability to Enjoyment. (pp. 31–42). Kluwer.

International Organization for Standardization (2018). Ergonomics of human-system interaction – Part 11: Usability: Definitions and concepts (ISO Standard No. 9241-11:2018). https://www.iso.org/standard/63500.html

Peters, D., Calvo, R. A., & Ryan, R. M [Richard M.] (2018). Designing for motivation, engagement and wellbeing in digital experience. Frontiers in Psychology, 9, 1–15.

Ryan, R. M [Richard M.], & Deci, E. L [Edward L.]. (2017). Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness. Guilford Publications.

User Experience Questionnaire. https://www.ueq-online.org/

Schrepp, M. (2015). User Experience Questionnaire Handbook. Available under:

https://www.researchgate.net/publication/281973617_User_Experience_Questionnaire_Handbook.

Vansteenkiste, M., & Ryan, R. M [Richard M.] (2013). On psychological growth and vulnerability: basic psychological need satisfaction and need frustration as a unifying principle. Journal of Psychotherapy Integration, 23(3), 263.

# PRODUCE

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