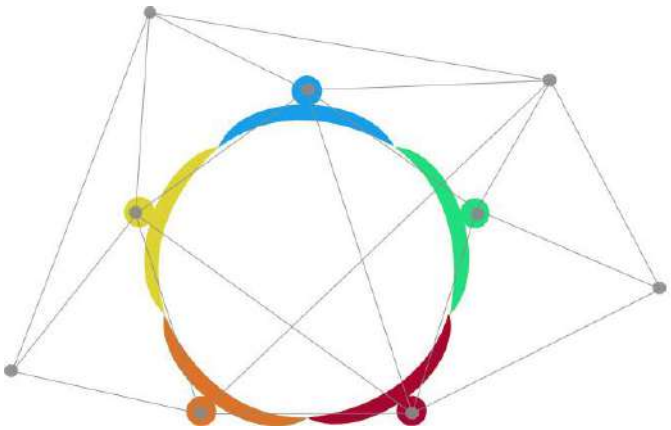

INEDIT

open INnovation Ecosystems
for Do It Together process

VALIDATION PROCESS SPECIFICATIONS

SUPSI

Version 2
09 2021

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Contributors	Versions	Dates	Revision Description
SUPSI	1.0	23/04/21	Preliminary draft
SUPSI	1.1	18/06/21	Added acceptance testing paragraph
SUPSI	1.2	06/08/21	Added unit testing and system testing paragraphs
SUPSI	1.3	10/09/21	Document finalization
TTS	1.4	15/09/21	Document review
ENSAM	2	01/10/21	Coordination check

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EXECUTIVE SUMMARY

This deliverable reports on the validation process aiming at evaluating the success of the entire INEDIT solution made up by the development and integration of various avant-garde tools and technologies. The validation methodology follows the V-model approach already introduced in D2.3, whose methodological thread consists of four main steps: unit testing, integration testing, system testing and acceptance testing. In this report, the integration testing will be not addressed since it will be the goal of work package 4. On the other hand, the other three steps first required a preliminary literature review, highlighting the most suitable platform KPIs and the characteristics they should have in order to be valuable and usable; then an interaction with the use case leaders and technology developers with the aim of defining ad hoc and consistent evaluation KPIs.

Specifically, the report is divided into four parts: the first two chapters are devoted to a brief introduction and the specification of the INEDIT validation approach. §3 is the core of the entire deliverable and, following the steps of the methodology, details the KPIs with a brief description and the related metric aimed at calculating the value. It is crucial to specify that the target values and benchmark for the validation are not defined in this document, but they will be determined in subsequently and complementary D6.6.

§4 contains the validation timeline defining a preliminary activity schedule of D6.6 and a brief risk analysis followed by mitigation actions. Finally, the document deals with the match between the high-level objectives (HLOs) specified in the DoA and the stakeholder requirements. Moreover, the annexes detail what stands behind the validation process presented in §3.

1. INTRODUCTION

INEDIT project, aimed at creating an open innovation European DIT ecosystem for sustainable furniture co-creation, leads to the development and implementation of avant-garde technologies concerning co-design and open manufacturing. In order to deliver sustainable, smart and personalised new products in a shorter time to market than usual, new tools and technologies need to be designed and developed, channelling the creativity of consumers and shaping it through designers' professional skills. These innovations come from WP3, which intends to design and develop all the tools enabling co-creation, as well as the platform that will host them, allowing stakeholders to access and interact with each other. Finally, the Sustainability Driven Orchestrator's implementation with the ERP module bridges the connection between the co-creation and the agile manufacturing network, enabling custom furniture production.

Strong innovation and massive development driven by the INEDIT customer-centred paradigm need to be applied, verified and validated, and this is where this deliverable comes in. The goal here is to present the methodology that will allow validating the results obtained through INEDIT implementation, which will be carried out within WP6 activities. The approach applied consists of starting from what has been done in WP2, especially in D2.3, with the framework for validation of use cases and evolving the analysis with specific KPIs that will allow the implementation evaluation afterwards.

The output of this work will be directly used and applied in the different demonstrators and in task 6.6 where the final validation of the entire INEDIT solution will be carried out.

1.1. Relationship of T6.1 with other tasks and WPs

Task 6.1 plays a central role in the demonstration and evaluation process, providing a foundational basis for the other WP6 tasks. The framework for evaluation and the KPIs will be the essential and major means for the validation and verification during the implementation of DIT solutions in each demonstrator. These relationships are depicted in Figure 1 and explained below.

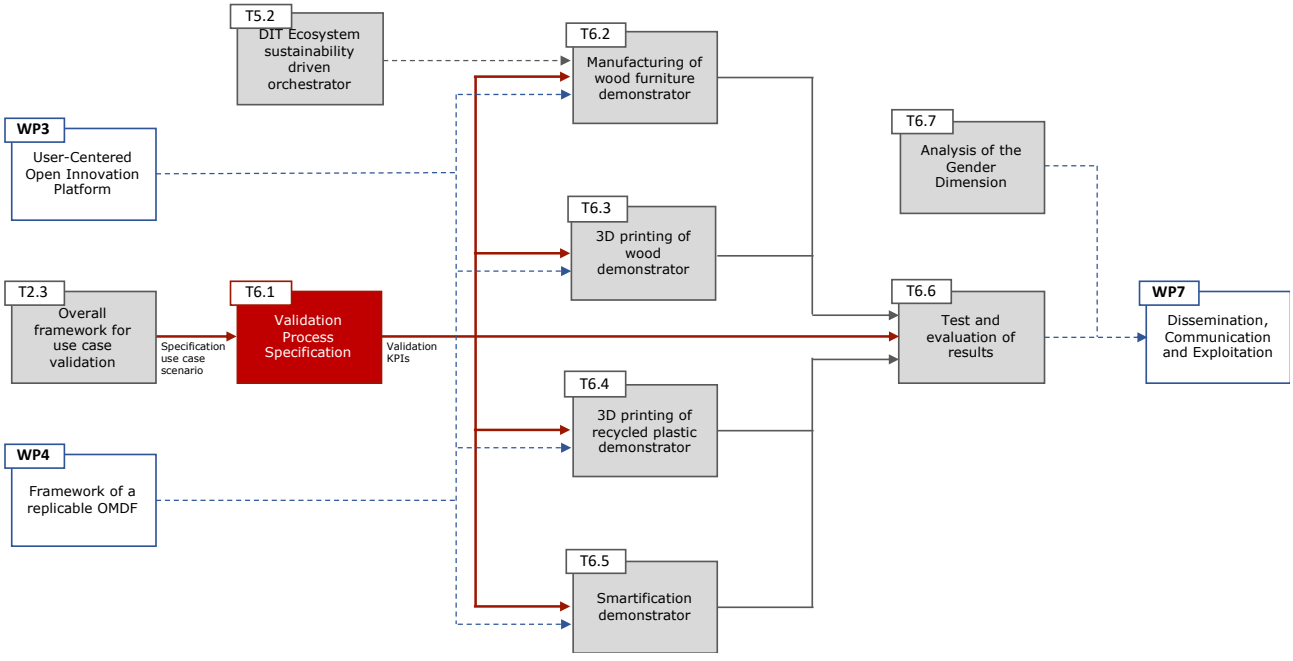

Figure 1 Relationship of T6.1 with other tasks and WPs

The interdependencies within WP6 are as follows:

- Tasks 6.2-6.5: these tasks address the integration and validation of the different scenarios; more in detail, they have been identified in different OMDFs, respectively at VERA, AIMEN, UL and UNINOVA facilities. Task 6.1 provides a set of means of verification, including steps, methodology and KPIs, ensuring a smooth and correct implementation of INEDIT DTI technologies.
- Task 6.6: the purpose of this task is to propose the criteria for the scenarios result evaluation and to apply those criteria to assess the final project demonstration campaign outcome. The final validation will also ensure that most of the high-level objectives (hereunder re-proposed), proposed by the project, will be completely satisfied, reflecting the initial objectives of the INEDIT project.

There is a direct relationship between T6.6 and WP7, in fact, the results of this task will pave the way for successful exploitation, pointing out the INEDIT solution strong points as well as aspects to be improved. Since T6.6 is the further development and application of what has been carried out in T6.1, the latter provides a fundamental and strong basis for exploiting the entire INEDIT solution.

Furthermore, T6.1 is strictly related to T2.3, since it could be considered as a preparation stage for WP6, where the demonstration scenarios are executed and evaluated in detail based on the framework and initial plan resulting from Task 2.3.

1.2. Connection with INEDIT GA objectives

As described before, the main goal of this deliverable is to develop and evolve the validation framework presented in D2.3, providing both a methodological approach and qualitative/quantitative KPIs in order to evaluate the INEDIT solution in the four demonstration scenarios. Task 6.1 must therefore ensure that in the subsequent tasks 6.2-6.5, specific initial requirements of the INEDIT project will be respected and evaluated.

The high-level objectives of the project, specifically outlined are:

1. To unleash creativity of consumers and designers towards co-creation of new pieces of furniture addressing the needs of the single user in an industrial context:
    a. To develop a framework of interactive technologies supporting co-creation and facilitating design
    b. To integrate interactive technologies with methodologies in an open innovation platform for DIT stakeholders
    c. To create specific training and accompaniment regarding co-creation with the DIT approach
2. To democratize the access to production resources in the furniture sector:
    a. To Design a DIT process focused on customer-driven production
    b. To create a new adapted open manufacturing process integrated in the DIT approach by:
        i. Networking production tools
        ii. Developing post-processors enabling “Design To Manufacturing” in one step
3. To support SME operating in the furniture sector in finding new business opportunities:
    a. To develop and demonstrate sustainable business models that validate the DIT process
    b. To support SMEs in integrating DIT as a new sustainable business opportunity
4. To create a framework of solutions for creation, engineering and distributed production of customer-driven pieces of furniture:

a. To develop a co-creation digital platform adapted to INEDIT process
b. To create a description of replicable Open Manufacturing Demonstration Facility
c. To demonstrate and evaluate the INEDIT process

5. To define design and manufacturing strategies focusing on lowering ecological impact and addressing societal challenges:
   a. To integrate global design capabilities and digital continuity in the INEDIT platform
   b. To develop a tool that integrates and monitor OMDFs' E-KPIS to sustain a low ecological impact
   c. To create agile supply chains for circular economy
   d. To integrate and monitor gender dimension in building and assessing the DIT process
6. To create an ecosystem of all stakeholders within Europe:
   a. To build and engage communities involving complementary actors in the DIT process

This work and the subsequent D6.6 aim at analysing the INEDIT solution in reaching some of the above-mentioned overall objectives, specifically n° **1a, 2a, 2b, 4a, 5b**. On the other hand, further ones will be verified within other work packages. The following table summarises the links among the high-level objectives and their work packages.

Objectives	Specific Objectives	Work Packages
HLO1	a. Interactive technologies supporting creativity b. Open Innovation Platform integration c. Training	- WP3 - WP6
HLO2	a. Consumer driven production process b. Networked production tools c. Machine instructions generation from designed furniture	- WP4 - WP5 - WP6
HLO3	a. Business models integrating DIT b. Supporting SMEs	- WP5 - WP6 - WP7
HLO4	a. INEDIT process b. OMDFs c. Co-creation platform	- WP3 - WP4 - WP6
HLO5	a. OMDF E-KPIs b. INEDIT evaluation of demonstrators c. Gender Analysis	- WP5 - WP6
HLO6	a. Building communities	- WP7

Table 1 Verification of High-Level Objectives of the project

2. METHODOLOGY

Through its twin digital and physical platform, the INEDIT project is intended to demonstrate the potential innovation around social manufacturing within the circular economy in designing global while producing locally. In this vision, technology plays an essential role in the success of this ecosystem. For such a reason, an entire work package is devoted to validating the technologies separately and the global INEDIT solution, ensuring that the initial requirements and intentions will be met and respected.

To support the specification process validation, the research methodology has considered different methods and steps:

Step 1. A **literature study** was conducted to define (i) the validation methodology introduced in D2.3, as well as the step that the latter requires to be performed (ii) the characteristics that KPIs need to have and (iii) preliminary KPIs supporting the validation process.

Step 2. **Interaction with demonstrator leaders**: a deep and continuous interaction with use cases leaders and technology developers enabled to deeply define the KPIs that will be used for both the validation of the single INEDIT technologies and the entire INEDIT solution.

Step 3. **Verification means' finalisation**: finalization of KPIs previously defined and design of additional verification means (questionnaires) in order to access tools and technologies TRL and MRL values.

Step 4. A **risk management plan** has been drawn up taking into account the possible risks that may arise both from the validation process and from its outcome.

Step 5. Verification HLOs satisfied: the last step was meant to verify that the original HLOs (DoA), stakeholders (D2.1) and system (D2.2) requirements will be successfully satisfied and demonstrated in the final solution.

Figure 2 represents the methodology previously described in terms of (starting from the left and going in a clockwise direction) inputs considered, controls to be respected, outputs provided and resources supporting the process.

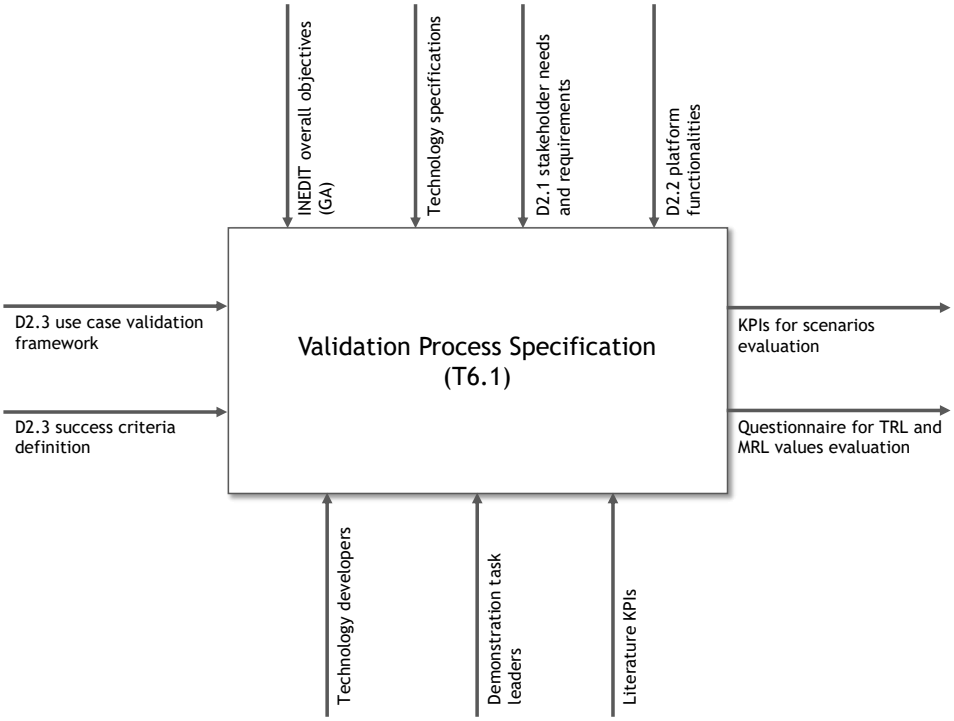

Figure 2 Methodology outline

2.1. Framework for the Use Cases Validation

This section is meant to present in-depth the validation approach already mentioned in D2.3. The framework explained below is the foundation of the future evaluation and validation process of the whole INEDIT solution, whose technologies will be demonstrated and analysed according to this methodology.

The approach to validation already introduces refers to the so-called V-model framework. The V-Model is a very popular model of the System Engineering process [1]; it was the first proposed by Paul Rook [2] in the late 1980s and is still in use today.

Mapping and describing the relationships between each phase of the development life cycle and its associated phase of testing is what this model is designed for, as well as improve the efficiency and effectiveness of software development [3]. The process steps representation is not structured following the traditional linear shape, but the verification and validation steps are bent upwards, forming the typical V shape. The latter steps are designed to test the solution previously developed following a well-defined path [4]:

- **Unit testing**. It involves checking that each feature specified in the component design has been implemented, focusing on the component individually.
- **Integration testing**. It addresses checking the integration of components into a unique solution.
- **System Testing**. It focuses on verifying that the entire system delivers the features required, checking the system as a whole.
- **Acceptance Testing**. Similar to the previous step, it checks the system as a whole but against the User Requirements, delivering what was requested by the customer.

2.1.1. Framework for INEDIT Solution Validation

This section presents the V-model approach applied to ensure a correct Use Cases Validation and that the INEDIT solution will meet the original requirement (functional and stakeholders).

Figure 3 illustrates a simplified sequence of the activities to be undertaken to design, implement, validate and evaluate the INEDIT technologies and platform integration. The activities are represented according to their temporal sequence, from left to right, and according to their level of abstraction, from the bottom to the top, following a V shape. The left wing of the V represents the design phases, which from the project concept and high-level objectives, through the elicitation and analysis of the users' requirements, lead to the definition of the platform architecture and to the specifications of the individual tools / technologies. At the bottom, there are the activities necessary to build the solutions, encompassing physical equipment as well as methods and tools, and the OMDFs. The activities on the right wing run from the testing of the individual INEDIT components within the different OMDFs to higher levels of integration and abstraction, such as the validation of the whole system with reference to the users' requirements, to the evaluation of the overall results in terms of transferability and exploitability throughout the concept of the OMD.

The two lower levels, L0 and L1, of the V-Model will be addressed by the work packages WP2, WP4 and WP6, in which the technologies and platform specifications are defined, the solutions built and verified.

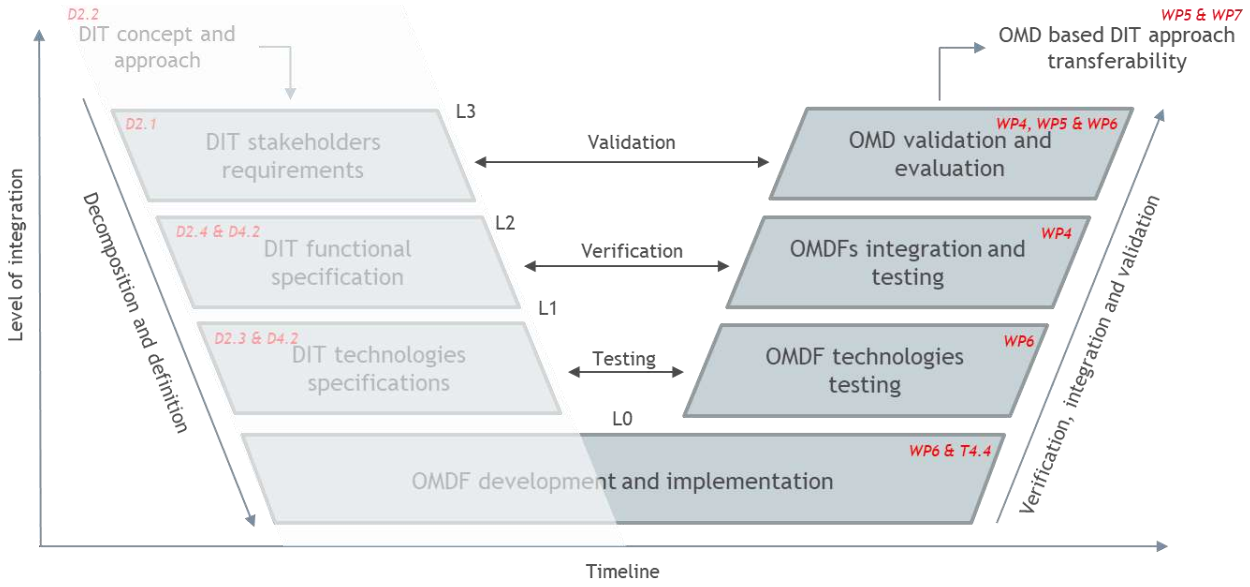

Figure 3 INEDIT Validation approach

It is a matter of fact that at this stage of the project, preliminary-foundation activities, such as stakeholder requirements (D2.1), DIT and platform specification (D2.2 and D4.2) and use case description (D2.3), as well as the technologies' development (WP3 and WP4), are almost done. The whole of these activities are the foundation of the following implementation and verification activities, carried out within WP6. Hence, the present document focuses on the V-Model's first and third levels (L1 & L3) and provides guidance to the activities of WP6 dedicated to the demonstration of the INEDIT approach through 4 use cases. The validation framework defines the activities to be performed to check that the INEDIT system meets the users' requirements and to assess the results of the demonstration activities carried out at the demonstrators' sites. Referring to the steps that the V-model framework consists, this document aims at providing the basis for (i) the unit testing that will be performed within T6.2-6.5, (ii) system testing and (iii) acceptance testing, both the latter will be performed within T6.6. On the other hand, the integration testing activity will be carried out within WP4.

2.2. KPI characteristics

To measure the effectiveness of the entire INEDIT solution and evaluate it with respect to the original high-level objectives (HLOs) and the succeeding stakeholder requirements, specific KPIs need to be set.

A key performance indicator (KPI) is a type of performance measurement [5]. Allowing monitoring process performances, they are widely adopted by organizations in order to evaluate how a company executes its strategic vision [6]. This means that KPIs can be used to verify if an organization is performing its activities following its strategy and objectives. Although metrics can help monitoring and evaluation, they must be defined following specific characteristic, otherwise, they may lead to incorrect evaluation or measurement.

The literature provides several characteristics that KPI must have in order to achieve their intent:

Warren J. [6] indicates that KPIs must (i) be conform to a company strategy and (ii) be easy to understand, allowing people to agree on what they are, what they mean, and (iii) monitor them.

Carlucci D. [7] says that essential for a KPI is to be (i) reliable - free from error and bias and faithfully represents what it purports to represent, (ii) comparable - enables users to identify similarities and differences between two sets of economic phenomena and (iii) understandable - be interpretable as well as easy to understand for users.

Kueng P. [8] defined six desired properties separating KPIs from other measures: (i) quantifiable – need to be quantitative, (ii) sensitive - easily detect the changes, (iii) linear - the variation of performance changes is congruent with one detected by the indicator, (iv) reliable, (v) efficient - created in the simplest way, and (vi) improvement-oriented - emphasizes improvement rather than conformity with instructions.

Furthermore, in order to develop an efficient and effective KPI, the latter must refer to SMART (Specific, Measurable, Attainable, Relevant and Time-Bound) objectives. The attitude of defining objectives considering SMART features enables most of the times to achieve performance success [9]. Taking into consideration the KPI characteristics previously mentioned and the objectives' characteristic that KPI has to monitor and evaluate, the following KPI features have been defined and considered during the following VALIDATION SPECIFICATION chapter:

- **Understandable:** it must be easy to understand, interpret and use, allowing people to easily detect a possible issue or bad performance.
- **Quantifiable:** it should be quantitative or, in case of qualitative, it must refer to a numerical scale.
- **Reliable:** it must be free from error and bias and faithfully represents what it purports to represent.
- **Efficient:** it must be designed in the simplest possible way, efficiently measuring and evaluate the objective it refers to.

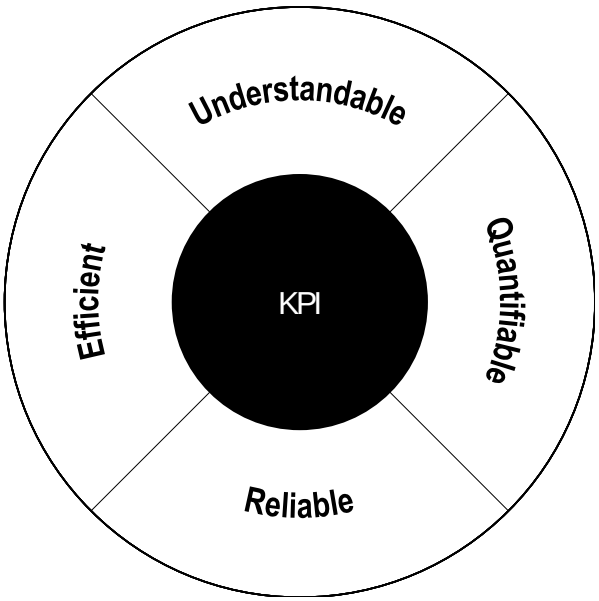

Figure 4 KPI's characteristics

3. VALIDATION SPECIFICATION

According to what has been previously stated in § 2.1, the undertaken validation process consists of three steps:

1. **Unit Testing**. It involves checking that each feature specified in the component design has been implemented, focusing on the component individually.
2. **System Testing**. It focuses on verifying that the entire system delivers the features required, checking the system as a whole.
3. **Acceptance Testing**. Similar to the previous step, it checks the system as a whole but against the User Requirements, delivering what was requested by the customer.

Unlike the literature presented before, the I**ntegration Testing** Step will not be performed in this document since it will be executed in WP4. Considering the **Unit Testing** process, it has been necessary to define few KPIs per each involved technology in order to monitor and control performance and results of the use cases in a proper manner. Regarding the **System Testing** process, it has been necessary to define some KPIs aimed at evaluating the performance and results of the INEDIT solution. Finally, taking into account the **Acceptance Testing** process, it has been necessary to check if the INEDIT solution meets users' requirements.

3.1. Unit testing

The **Unit Testing** process is meant to check that each feature specified in the component design has been implemented, focusing on each component individually. In other words, in this step, it has been necessary to define few KPIs per each involved technology in order to monitor and control the performance and results of the use cases in a proper manner. Find below the list of KPIs aimed at evaluating all the technologies involved in the INEDIT project. Such KPIs have been suggested by the owners of each technology and discussed, ensuring total coverage of the functionalities.

Technology (Leader)	Name	Description	Metric
INEDIT website based on Fanvoice platform (CROWD)	Website traffic [nr]	Total number of visitors (unique and cumulated) that visited at least one page of the website	$total\ \#\ of\ visitors\ of\ the\ website$
	Subscription ratio [%]	Percentage of visitors that creates an account on the website (i.e. subscriber or member)	$\frac{total\ \#\ of\ members}{total\ \#\ of\ unique\ visitors\ of\ the\ website} \times 100$
	Members per profile [%]	Percentage of subscribers per profile category	$\frac{total\ \#\ of\ members\ per\ profile}{total\ \#\ of\ members} \times 100$

	Website attractivity [%]	Percentage of projects created	$\frac{total\ \#\ of\ projects\ created}{total\ \#\ of\ unique\ visitors\ of\ the\ website} \times 100$
	Ongoing projects [nr]	Number of ongoing projects	$total\ \#\ of\ ongoing\ projects$
	Contribution ratio [%]	Percentage of people who contributed to a project by posting a comment or a like (i.e. contributors)	$\frac{total\ \#\ of\ projects\ with\ design\ validated}{total\ \#\ of\ participants^*} \times 100$ **participant = a person who visits a project page being logged to his account*
	Finalised projects ratio [%]	Percentage of projects finalized, that you can find into the product catalogue	$\frac{total\ \#\ of\ projects\ with\ design\ validated}{total\ \#\ of\ projects\ on\ the\ website} \times 100$
Creativity tool for furniture drawing (ENSAM)	Number of ideas [nr]	Number of sketches generated to represent an idea or a concept of furniture	$total\ \#\ of\ ideas\ of\ furniture\ uploaded\ to\ server$
	Complexity of sketches [nr]	Number of individual drawings that represent a sketch	$total\ \#\ of\ ideas\ for\ a\ single\ piece\ of\ furniture\ uploaded\ to\ sever$
	Scanned context adaption [nr]	Checks the use of the feature to erase scan of the environment	$total\ \#\ of\ points\ erased\ from\ the\ scan\ to\ draw$
	Capability of reverse changes [nr]	Count the number of changes reverse in an idea / sketch representation	$total\ \#\ of\ "Reverse\ changes"\ action$
	Meeting quality of experience [nr]	Assess the quality of experience perceived by a user by a questionnaire at the end of the creativity session	$total\ \#\ of\ the\ experience\ (Likert\ scale)$

	Tool responsiveness [ms/sec]	Assess average of the latency issues or quality of network	$average\ of\ latency\ in\ packets\ sent$
	Sketch duration [sec/hr/days]	Time spent by the user to complete a sketch	$time\ of\ design\ validation - time\ of\ the\ first\ draw$
	Sketch usability [nr]	Number of times that the sketch is used outside of the tool	$total\ \#\ of\ exports\ or\ screen\ captures$
Immersive Furniture Aided Design tool (ENSAM)	Complexity of the furniture [nr]	Counts the number of different parts representing the furniture	$total\ \#\ of\ parts\ making\ the\ furniture$
	Complexity of operations [nr]	Counts the number of paths of the furniture tool	$total\ \#\ of\ individual\ operations\ to\ get\ a\ part$
	Mesh complexity [nr]	Counts the mesh complexity to be rendered real-time in other applications	$total\ \#\ of\ vertices\ or\ triangles$
	Number of furniture created parts [nr]	Number of parts created by the user to design the furniture	$total\ \#\ of\ the\ parts\ uploaded\ to\ server$
	Number of panels used [nr]	Number of panels and generic created parts to design all the furniture This corresponds to the way the user has optimised his parts creation (make one or more parts with only one panel)	$\frac{total\ \#\ of\ furniture\ parts}{total\ \#\ of\ panels\ used\ to\ produce\ furniture}$
	Data exported from the furniture (for User)	Readability and clarification of the assembly instructions	$user\ satisfaction\ level\ (rating\ after\ session)$
	Number of iterations over a design based on	Number of iterations needed before manufacturer	$total\ \#\ of\ versions\ of\ the\ design\ before\ validation$

	manufacturer's feedbacks [nr]	validates the design production	
	Time of assembly [sec/min]	Time used to assemble furniture's parts	$time\ of\ last\ added\ piece\ of\ furniture - time\ of\ the\ first\ part\ selection$
	Number of measurements required [nr]	Number of manual measurements required to perform the design / to prevent scan imprecision	$total\ \#\ of\ measurements\ asked\ by\ the\ designer$
	VR Quality Experience	User quality experience	$UX\ satisfaction\ (Likert\ scale)$
3D configurator tool (ENSAM)	Number of Customized Features [nr]	Number of features that can be tailored/selected by the customer	$total\ \#\ of\ feature\ provided\ by\ the\ tool$
	Level of customization of the furniture [nr]	Number of parametric choices made by the users to customize furniture	$total\ \#\ of\ changes\ made\ by\ the\ user$
INEDIT Mobile app (TTPSC)	Time to scan a room [sec]	The time the user has been spending to scan the area	$time\ of\ scanned\ room\ visualization - time\ of\ starting\ the\ scan$
	Scan size [MB]	The size and complexity of the scan	$weight\ of\ the\ file$
	AR quality of experience	Assess the quality of experience perceived by a user	$rating\ of\ the\ experience\ (Likert\ scale)$
	Application responsiveness [ms/sec]	Assess the latency issues or quality of network	$average\ latency\ in\ packets\ sent$
ERP post-processing module (TTS)	Manufacturers' characterization [nr]	Number of manufacturers characterized	$total\ \#\ of\ manufacturers\ characterized\ by\ the\ tool$
	Production technologies	Number of technologies characterized	$total\ \#\ of\ technologies\ characterized\ by\ the\ tool$

	characterizatio n [nr]	(to be associated with manufacturers)	
	List of production solutions [nr]	The number of alternative solutions allowing to evaluate cost, time, impact choice	$total\ \#\ of\ solution$
	Manual technician intervention	A 3-level scale (low, medium, high) representing the need of technician's intervention to modify the files generated before sending them to production	$choice: \{low, medium, high\}$
Sustainability Driven Orchestrator (SUPSI)	Sustainability Modelling	Number of processes saved within the INEDIT ecosystem	$total\ \#\ of\ process\ saved$
	SDO Exploitation	Number of sustainability assessment calculation executed within the INEDIT ecosystem	$total\ \#\ of\ executed\ assessments$
	Process Sustainability Customization Intensity	Number of customized processes, according to the sustainability perspective, over the total number of processes included in the use case	$\frac{total\ \#\ of\ customized\ processes}{total\ \#\ of\ processes\ of\ the\ use\ case}$
Furniture production system (VERA)	CAD files set-up time [min/h]	Amount of time needed by the technicians to set-up the CAD executive files	$total\ amount\ of\ time\ required\ to\ setup\ a\ CAD\ file$
	BOM generation [min/h]	Amount of time needed by the	$total\ amount\ of\ time\ required\ to\ define\ the\ BOM\ per\ order$

		technicians to define the Bill of Material per each order	
	Assembly set-up [min/h]	Amount of time spent to prepare the instruction sheet (2D view of the furniture and the components)	$total\ amount\ of\ time\ for\ making\ the\ instruction\ sheet$
	Production set-up	Time spent to prepare and check the production files (i.e. to make the optimization for the panel cutting)	$total\ amount\ of\ time\ for\ setting\ up\ the\ production\ order$
	Number of non-compliant products	Numbers of wooden pieces or number of final products non-compliant from the machines (due the platform files) or for the customer	$total\ \#\ of\ non\ compliant\ pieces\ or\ products$
Innovative woodworking processing (SCM)	Ease of positioning [nr]	Number of displacements needed by the operator in order to complete the positioning of a single holding mean	$total\ \#\ of\ displacements$
	Setup time [sec/min]	Time needed in order to complete the setup of the working table	$total\ amount\ of\ time\ spent\ for\ setting\ up\ the\ machine$
	Setup errors [nr]	Number of errors occurred during the setup. In other words, number of errors present by the time the operator turns on the machine and starts to	$total\ \#\ of\ error\ occurred$

		make the woodworking process	
Modular robotic cell (AIMEN)	Percentage of wood in final piece [%]	Percentage of wood fibers included in the final piece by weight.	$\frac{kg\ of\ wood\ fibers}{kg\ of\ piece}$
	Deposition rate [kg/h]	Amount of raw material processed per unit of time.	$\frac{kg\ of\ deposited\ material}{hour}$
	Pre-process time [h]	Mean time from the order reception to the production start. Covers machine setup and trajectory generation.	$total\ \#\ of\ hours\ per\ piece\ for\ setup\ and\ trajectory\ genration$
	Production time [h]	Mean time to produce the pieces by 3D printing.	$total\ \#\ of\ printing\ hours\ per\ piece$
	Post-process time [h]	Mean time to treat the pieces to achieve good surface finishing.	$total\ \#\ of\ hours\ per\ piece\ for\ post\ processing$
Fused Granular Fabrication and desktop plastic injection (UL)	Waste cleaning time [min]	Amount of time spent for cleaning certain plastics that can potential be usable	$total\ \#\ of\ time\ for\ cleaning^{*}\ and\ drying$ **cleaning in aqueous solutions of NaOH for varying from 60°C to 90°C*
	Waste qualification time [kg/10 min]	Evaluation of the Melt Flow Index	$melt\ flow\ index\ measurement$
	Feedstock qualification [mm]	Shredding process and evaluation of the useful granulometry for printing	$size\ distribution\ of\ pellets$
	Printability [Y/N]	It is related to the technical feasibility of obtaining a reproductible printing with a	N/A

		particular plastic. This means that if the plastic has the conditions to be extruded, has a uniform geometry after extrusion and then has the sufficient thermal energy to stick to the deposited layer without deforming the geometry, in that moment, we can consider that it is printable.	
	Print Quality [MPa]	Tensile strength curves (MPa) and Elastic modulus (MPa) are used to evaluate the mechanical resistance of the part. This concerns the influence of process parameters on quality of the process.	$Tensile\ strength\ curves\ and\ Elastic\ moduls$
	Percentage of recycled material [%]	Blending ratio of recycled and virgin material in the printed object	$\frac{total\ amount\ of\ recycled\ material}{total\ amount\ of\ virgin\ material}$
	Mass flow printing time [kg/h]	Average quantity of material flow rate for printing.	$\frac{total\ amount\ of\ material\ laid\ down}{total\ printing\ time}$
Smart collector of plastic waste (UL)	Number of collectors [nr/km2]	Total number of collectors in a certain area	$\frac{total\ \#\ of\ collectors}{area}$
	Plastic collected [kg/week]	Historical data of collected plastic waste	$\frac{total\ amount\ of\ raw\ plastic\ waste}{period\ of\ time}$
	Transport [km]	Overall distance from raw material collection points	$distance\ from\ collection\ points\ to\ recycling\ facilities$

		to recycling facilities	
Smartification of furniture (UNIN)	Smartification need-constraints matching	Match each user' smartification needs to at least one or more smartification functionalities	$\frac{total\ \#\ of\ smartification\ functionalities}{total\ \#\ of\ user\ smartification\ needs}$
	Requirements validation	Each smartification functionality is valid and has at least one possible solution	$\frac{total\ \#\ of\ solutions}{total\ \#\ valid\ smartification\ functionalities}$
	Solution fulfilment	Each solution has at least one viable implementation (prototype)	$\frac{total\ \#\ viable\ implementation\ (prototype)}{total\ \#\ of\ solutions}$
	Component Availability	All hardware components required for the solution implementation have a supplier and are available for use.	$\frac{total\ \#\ of\ implementation\ hardware\ components}{otal\ \#\ of\ available\ components}$

3.1.1. TRL and MRL values

Furthermore, SUPSI has developed a questionnaire aimed at evaluating the technology readiness level (TRL) and the market readiness level (MRL) of each involved technology. Such questionnaires should be filled as a checklist at the end of the technologies' development to verify if the initial proposed values have been reached.

TOP LEVEL VIEW -- Demonstration Environment **(Start at top and pick the first correct answer)**	**Checkbox (y/n)**	**Continue with**
Has the technology component been successfully used in an operational scenario?		TRL 9
Has the technology component been qualified for an operational scenario but not operationally demonstrated?		TRL 8
Has a prototype technology component been demonstrated in an operational environment?		TRL 7
Has a prototype been demonstrated in a relevant scenario, on the target or surrogate platform?		TRL 6
Has a breadboard technology component been demonstrated in a relevant (typical; not necessarily stressing) scenario?		TRL 5

Has a breadboard technology component been demonstrated in a laboratory (controlled) scenario?		TRL 4
Has experimental proof-of-concept been demonstrated?		TRL 3
Has a concept been formulated?		TRL 2
Have basic principles been observed?		TRL 1
None of the above		TRL 0

Table 2 TRL questionnaire

TOP LEVEL VIEW -- Demonstration Environment (Start at top and pick the first correct answer)	Checkbox (y/n)	Continue with
Have all the validation KPIs been surpassed and a growth predicted?		MRL 9
Have stable sales pipeline and strong understanding of the market allowed any revenue prediction?		MRL 8
Have team and customers been satisfied by the evidence of progress?		MRL 7
Has the campaign been matched with paying customers?		MRL 6
Has the campaign been ran with early adopters?		MRL 5
Has the campaign been ran with stakeholders?		MRL 4
Have you received an initial "offering"? Have stakeholders expressed interest in your solution?		MRL 3
Have needs been articulated using a customer/user story?		MRL 2
Have the needs been described but without having any evidence?		MRL 1
None of the above		MRL 0

Table 3 MRL questionnaire

3.2. System testing

The **System Testing** process focuses on verifying that the entire system delivers the features required, checking the system as a whole. In other words, in this step it has been necessary to define some KPIs aimed at evaluating the performance and results of the INEDIT solution. Find below the list of KPIs, suggested by SUPSI after an in-depth literature analysis, aimed at evaluating the overall system performance.

ID	Name	Description	Metric
01	First Response Time [min/h/days]	Time between the user request/message and expert response/answer	$time\ designer\ answer\ -\ time\ designer\ selected$
02	Bounce Rate [%]	Percentage of visitors who enter the site and then leave	$\frac{total\ \#\ of\ website\ visitors\ who\ left\ without\ any\ interation}{total\ \#\ of\ website\ visitors} \times 100$
03	Profile subscription Rate [%]	Percentage of platform subscribers per category over total amount of subscribers	$\frac{total\ \#\ of\ subscribers\ of\ category\ i}{total\ \#\ of\ subscribers} \times 100$

			$*i \in$ *profiles categories*
04	Retention Rate [%]	Percentage of visitors that start a project	$\frac{total\ \#\ of\ website\ visitors\ that\ start\ a\ project}{total\ \#\ of\ website\ visitors} \times 100$
05	Overall Project time [days]	Time between the creation and completion of a project (including the manufacturing steps)	$time\ furniture\ completion\ -\ time\ project\ creation$
06	Design Lead Time [days]	Time between the initiation and completion of the design process	$time\ design\ validated\ -\ time\ designer\ acceptancy^*$ ** time designer acceptancy = the day starting from the designer decide to collaborate on this project*
07	Manufacturing acceptancy [days]	Time between the user submission of the design for the first time and the acceptancy by the manufacturer	$time\ manufactuiring\ acceptancy\ -\ time\ user\ submission$
08	Manufacturing Lead Time [days]	Time between the manufacturing process completion (realisation of the physical products) and the manufacturing acceptancy	$time\ manufacturing\ process\ completion - time\ manufactuiring\ acceptancy$
09	Average Conversion Rate [%]	Number of visitors who have completed their actions successfully	$\frac{total\ \#of\ website\ visitors\ that\ buy\ or\ design\ a\ product}{total\ \#\ of\ website\ visitors} \times 100$
10	Simplified Promoter score	Simple index summarising the perceived experience within the platform	$\frac{\sum customers\ experience\ score^*}{total\ \#\ of\ customers}$ ** 0 = not recommended; 1 = recommended*
11	Customer Effort Score	How much effort the customer takes to jointly complete the product definition	$\frac{\sum customers\ effort\ score^*}{total\ \#\ of\ customers}$ ** 1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high*
12	Project-designer Assignment [Y/N]	Indicate if a project has been assigned to a designer	N/A
13	Project-manufacturer Assignment [Y/N]	Indicate if a project has been assigned to a manufacturer	N/A
14	Expert Workload [%]	Indicate the number of projects assigned to an expert	$\frac{total\ \#\ of\ running\ projects\ assigned\ to\ an\ expert\ i}{total\ \#\ of\ running\ projects} \times 100$ $*i \in$ *profiles categories*

15	Number of manufacturers fulfilling customer requirements [nr]	Indicate the potential number of manufacturers able to satisfy a customer requirement	$\sum_{i=1}^{N} manufacturing\ acceptancy_i$ $*N = total\ number\ of\ manufacturers$
16	Assigned stakeholders category	Number of stakeholder category assigned to a project	$\frac{total\ \#\ stakeholder\ categories\ assigned\ to\ each\ project}{total\ \#\ stakeholder\ categories}$
17	Needs' Coverage	Indicate the ratio between the formalized customer needs and the expressed ones directly by the customer	$\frac{total\ \#\ customer\ needs\ formalised^*}{total\ \#\ customer\ needs\ exspressed}$ $*formalised = understood\ and\ taken\ into\ account\ by\ the\ experts$
18	Concepts proposed [nr]	Number of proposed concepts (sketches and designs) by the experts to the customer	$total\ \#\ of\ propoed\ concepts\ by\ the\ experts$
19	Requirements fulfilment	Ratio between the sum of values of the chosen solution requirements and the sum of values of the initial customer requirements	$\frac{\sum_{i=1}^{\#\ of\ customer\ satisfied\ requirements} weight_i}{\sum_{z=1}^{\#\ of\ customer\ requirements} weight_z}$ $*i \in customer\ satisfied\ requirements;$ $*z \in customer\ requirements;$ $*I \subseteq Z$
20	Materials used	Number of materials used for the final solution chosen by the customer	$total\ \#\ of\ materials\ composing\ the\ final\ solution$
21	Supplier per Material [nr]	Number of supplier able to supply a specific material	$total\ \#\ of\ suppliers\ for\ the\ material\ i$
22	% of Recycled of the Product [%]	Percentage that expresses the amount of used recycled material per product	$\frac{total\ recycled\ components\ weight}{total\ product\ weight} \times 100$
23	Impact avoided	Total impacts avoided by the best scenario vs the worst one. This indicator is calculated per use case, considering all the comparisons required to the SDO	$\sum_i BSI_i - WSI_i$ $*BSIi = best\ scenario\ impacts\ of\ the\ i\text{-}th\ comparison$ $*WSIi = worst\ scenario\ impacts\ of\ the\ i\text{-}th\ comparison$

3.3. Acceptance testing

Pursuing the V-model methodology adopted so far, the last step is meant to verify that the stakeholder requirements outlined in D2.1 will be met and implemented in the final INEDIT solution. Meeting market demands is fundamental to ensure the success and further development of the entire INEDIT ecosystem in the medium and long term; therefore, a detailed analysis has been undertaken to compare what the

platform will demonstrate through the use cases against what the platform was designed for and the stakeholders' requirements.

Linking these different aspects also enables to bridge outputs of various deliverables, such as D2.1 concerning the stakeholder analysis (see Figure 5), D2.2 regarding platform requirements (see Figure 6) and D4.2 respecting DIT platform functions (see Figure 7) as, showing and verifying the consistency of the INEDIT solution development. This task has been performed going through three main linking phases:

- Stakeholder Requirements and System Requirements;
- System Requirements and DIT Processes;
- DIT Processes and DIT Functions.

Here is the logical flow that drives the established linkages:

Stakeholder Requirement → System Requirement → DIT Process → Sub-Function → Function

More in detail, the first step has been linking the stakeholders' requirements detailed in D2.1 and listed in Figure 5 with the System Requirements. The latter, coming from the DIT processes (D2.2), correspond to specific features the platform must have in order to offer some functionalities required by the DIT approach. Specifically, building this bridge enables to verify which functionalities support the initial stakeholders' requirements. In other words, demonstrating the implementation of these system requirements will allow verifying which market needs are met (i.e. stakeholder requirements).

In order to show the established links, a section of System requirements and the DIT process from which they come from is reported (Figure 6).

ID requirement	Requirement	Valuable aspects	Addressed stakeholders
SKH_RQ1	To ease customer experience in furniture design, by improving customization activity, using innovative technologies, providing experts support.	Furniture customization level Adopted innovative technolgies Visualization of products in real environments Experts support Easy to use platform	Consumers Business customers
SKH_RQ2	To increase product transparency, in terms of quality features of furnishing product and its environmental impacts.	Communication of product features, materials, costs, producer(s) and sustainability aspects	Consumers Business customers
SKH_RQ3	To improve services for customers after furniture purchasing	Tracking of products Management of EoL of products Furniture smartification	Consumers Business customers
SKH_RQ4	To enhance the involvement and support of local producers	Communication with the producers Delivery time and costs	Business customers Furniture producers
SKH_RQ5	To ensure secure exchange of data.	Data sharing along the value chain	All
SKH_RQ6	To ensure data and systems interoperability.	Communication between different technologies, formats and actors	Furniture producers Furniture producers' suppliers Service providers
SKH_RQ7	To establish an effective communication channel between INEDIT stakeholders	Experts support Community involvement Users feedback collection	All

Figure 5 Stakeholder requirements (from D2.1)

SYS_RQ1 Accelerate Ideas and support design		
ID Requirement	Platform Requirement	Corresponding ID_DIT process
SYS_RQ1_1	Facilitate data collection *Data from users' problem shall be collected. These data make it possible to integrate the ins and outs of the problem to be solved.*	1_1_1
SYS_RQ1_2	Examine the context and the problem *The context and the users' problem shall be examined by the experts.*	1_1_1
SYS_RQ1_3	Propose similar solutions to the problem encountered *Similar solutions to the problem encountered shall be proposed in order to satisfy the user based on the problem definition (size, functionality, materials...)*	1_1_1
SYS_RQ1_4	Facilitate the understanding and validation of the problem *The understanding and validation of the problem shall be facilitated directly on the platform.*	1_1_2

Figure 6 Example of system requirements and related DIT processes (D2.2)

Finally, some linkages among the DIT process and functions have been created, the latter presented and detailed in D4.2. Particularly, each function represents a set of processes (hierarchically, functions are higher than DIT processes). These links ensure that a subset of DIT processes will be covered and demonstrated by the four planned use cases.

PF1.1. The demonstrator must provide information on the context, the capture and classification of the request (WP2.2: 1_Empathization)
PF 1.1.1. The demonstrator must collect data provide information on the context, the capture and classification of the request (WP2.2: 1.1.1_Communicate).
PF 1.1.2: The demonstrator must understand the users' problem (WP2.2: 1.1.2_Search/understand the problem)
PF1.1.3: The demonstrator must analyse conscious and unconscious user needs (WP2.2: 1.2.1_Analyse conscious and unconscious user needs)

Figure 7 Example of functions and related DIT processes (from D4.2)

The completed links discussed above are presented in Appendix A according to the logical flow explained before, hereunder and example of how the connections look like.

Stakeholders Requirements	Platform Requirement (2)	Platform Requirement (1)	ID_DIT process	Function (3)	Function (2)	Function (1)
SKH_RQ1	SYS_RQ1_1	SYS_RQ1	1_1_1	PF 1.1.1.	PF 1.1.	PF 1.

Figure 8 Example of links among SKH_RQ, DIT process, platform req. and function

The analysis carried out so far has been used as a basis for the last phase, aiming at linking the DIT processes and functions to the four use cases' steps. Such links have been established in order to understand which processes would have been tested because of the use case scenarios and therefore which system and stakeholder requirements would have been involved. This check is extremely crucial since the designed use cases will not allow testing the overall set of DIT processes and requirements. This verification has been done for each of the four use cases and is reported in Appendix B, Appendix C, Appendix D and Appendix E.

4. VALIDATION TIMELINE AND RISK EVALUATION

The current document aims at providing a structural framework and practical means for the final project validation. To successfully validate the entire INEDIT ecosystem and its embedded tools and technologies, it has been necessary to adapt an efficient and effective evaluation strategy that consists of developing specific means and defining the stages leading to the completion of the validation process.

As described before, this deliverable is strictly connected to D6.6, where the final validation will be carried out through the definition of targets and benchmark for the KPIs and metrics defined so far. Particularly, tasks from 6.2 to 6.5 are meant to demonstrate the implementation of the INEDIT development and concepts through four different use cases that will pave the path for the final validation. Those tasks will start collecting data and verifying that all the defined KPIs can be applied later on. This activity might be critical considering future tasks: in case of the lack of data during the final validation (task 6.6), it will be impossible to achieve both the goals of the task itself and of the project. For this reason, this deliverable provides a consistent methodology explaining in detail what the KPIs are designed for as well as when and where they will be applied, mitigating the possible issues in the further tasks. Moreover, the development of TRL and MRL questionnaires helps to prevent the chance of not achieving the expected technologies developments and consequently the inability of gathering the desired data for the validation. Not least is to consider the actual pandemic situation and the possible future evolution: the failure to test the entire INEDIT solution physically might not be a critical issue; in fact, most of the technologies can be virtually tested, and the connected data will be somehow collected and analysed while the furniture manufacturing can be tested separately in a safe environment.

The following Gantt drafts the validation timeline adopted so far and presents the further steps to be addressed.

	mar-21	apr-21	mag-21	giu-21	lug-21	ago-21	set-21	ott-21	nov-21	dic-21	gen-22	feb-22	mar-22	apr-22	mag-22	giu-22	lug-22
TASK 6.1 - Validation Process Specification							D6.1										
Validation Timeline																	
Literature Analysis on KPIs																	
Direct interactions among SUPSI and use case leaders																	
KPIs & formulas definition																	
TASK 6.2 - TASK 6.5																	
TASK 6.6 - Test and Evaluation of Results																	D6.6
Validation in use case implementation																	
Iterative feedbacks collection for improvements																	
Final use case validation																	
Alignment with WP4 activities																	

Figure 9 Gantt WP6

5. CONCLUSION

This deliverable builds the backbone for the validation methodology aimed at assessing the overall user experience and designed use case scenarios to demonstrate the effectiveness of the INEDIT solution in attending the stakeholders' requirements and the related system requirements (see §3). The analysis of the fulfilment of such needs has brought to the definition of a further check. Indeed, it has been verified if a portion of the defined high-level objectives (HLOs) related to such work package has been satisfied. In order to do that, it has been necessary to define some connections among HLO and stakeholders' requirements summarised in the table below.

High Level Objective	Stakeholders Requirements
HLO1a - To develop a framework of interactive technologies supporting co-creation and facilitating design	**SKH_RQ1** - To ease customer experience in furniture design, by improving customization activity, using innovative technologies, providing experts support
HLO2a - To Design a DIT process focused on customer-driven production	**SKH_RQ1** – To ease customer experience in furniture design, by improving customization activity, using innovative technologies, providing experts support **SKH_RQ6** - To ensure data and systems interoperability
HLO2b - To create a new adapted open manufacturing process integrated in the DIT approach	**SKH_RQ1** – To ease customer experience in furniture design, by improving customization activity, using innovative technologies, providing experts support **SKH_RQ6** - To ensure data and systems interoperability
HLO4a - To develop a co-creation digital platform adapted to INEDIT process	**SKH_RQ1** – To ease customer experience in furniture design, by improving customization activity, using innovative technologies, providing experts support **SKH_RQ2** – To increase product transparency, in terms of quality features of furnishing product and its environmental impacts **SKH_RQ4** – To enhance the involvement and support of local producers **SKH_RQ7** - To establish an effective communication channel between INEDIT stakeholders
HLO5b - To integrate global design capabilities and digital continuity in the INEDIT platform	**SKH_RQ2** – To increase product transparency, in terms of quality features of furnishing product and its environmental impacts **SKH_RQ4** – To enhance the involvement and support of local producers **SKH_RQ7** - To establish an effective communication channel between INEDIT stakeholders

Figure 10 HLOs and Stakeholder Requirements matching

Therefore, according to such table, attending the reported stakeholder requirements will allow fulfilling the related high-level objectives (HLOs).

The application of the adopted validation methodology, related to the V-model approach, has brought to several results:

- Definition of several key performance indicators (KPIs) aimed at evaluating the development of specific tools and technologies through interactions with involved technology providers (Unit Testing according to the V-model nomenclature)
- Definition of several key performance indicators (KPIs) aimed at evaluating the overall INEDIT solution (System Testing according to the V-model nomenclature)
- Definition of several linkages among D2.2 and D4.2 aimed at verifying that the initially defined stakeholder requirements will be satisfied by some of the features of the INEDIT solution.

At last but not at least, it must be underlined that such deliverable is strictly related to the upcoming tasks of the same work package. More in detail, such document provides the indicators with whom use case leaders will evaluate the results of the designed testing scenarios. Moreover, such report will be the basis for evaluating the data that will be collected during the execution of the demonstrators (T6.2 – T6.5) and to define target and benchmarking values (D6.6).

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7. APPENDIX

7.1. Appendix A

Stakeholders Requirements	Platform Requirement (2)	Platform Requirement (1)	ID_DIT process	Function (3)	Function (2)	Function (1)
SKH_RQ1	SYS_RQ1_1	SYS_RQ1	1_1_1	PF 1.1.1.	PF 1.1.	PF 1.
SKH_RQ1	SYS_RQ1_2	SYS_RQ1	1_1_1	PF 1.1.1.	PF 1.1.	PF 1.
SKH_RQ1	SYS_RQ1_3	SYS_RQ1	1_1_1	PF 1.1.1.	PF 1.1.	PF 1.
SKH_RQ1	SYS_RQ1_4	SYS_RQ1	1_1_2	PF 1.1.2.	PF 1.1.	PF 1.
SKH_RQ1	SYS_RQ1_5	SYS_RQ1	1_2_2	PF 1.1.4.	PF 1.1.	PF 1.
SKH_RQ1	SYS_RQ1_6	SYS_RQ1	2_1_2	PF 1.2.2.	PF 1.2.	PF 1.
SKH_RQ1	SYS_RQ1_7	SYS_RQ1	2_1_2	PF 1.2.2.	PF 1.2.	PF 1.
SKH_RQ1	SYS_RQ1_8	SYS_RQ1	2_2_1	PF 1.2.3.	PF 1.2.	PF 1.
SKH_RQ1	SYS_RQ1_9	SYS_RQ1	2_2_1	PF 1.2.3.	PF 1.2.	PF 1.
SKH_RQ1	SYS_RQ1_10	SYS_RQ1	2_2_2	PF 1.2.4.	PF 1.2.	PF 1.
SKH_RQ1	SYS_RQ1_11	SYS_RQ1	3_1_1	PF 1.3.1.	PF 1.3.	PF 1.
SKH_RQ1	SYS_RQ1_12	SYS_RQ1	3_1_1	PF 1.3.1.	PF 1.3.	PF 1.
SKH_RQ1	SYS_RQ1_13	SYS_RQ1	3_1_2	PF 1.3.2.	PF 1.3.	PF 1.
SKH_RQ1	SYS_RQ1_14	SYS_RQ1	3_2_1	PF 1.3.3.	PF 1.3.	PF 1.
SKH_RQ1	SYS_RQ1_15	SYS_RQ1	3_2_2	PF 1.3.4.	PF 1.3.	PF 1.
SKH_RQ1	SYS_RQ1_16	SYS_RQ1	4_2_2	PF 1.4.4.	PF 1.4.	PF 1.
SKH_RQ1	SYS_RQ1_17	SYS_RQ1	4_2_2	PF 1.4.4.	PF 1.4.	PF 1.
SKH_RQ1	SYS_RQ1_18	SYS_RQ1	5_2_1	PF 1.5.3.	PF 1.5.	PF 1.
SKH_RQ1	SYS_RQ1_19	SYS_RQ1	5_2_1	PF 1.5.3.	PF 1.5.	PF 1.
SKH_RQ1	SYS_RQ1_20	SYS_RQ1	6_1_1	PF 1.6.1.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ2_1	SYS_RQ2	/	/	/	/
SKH_RQ1	SYS_RQ2_2	SYS_RQ2	1_1_2 1_2_1 2_1_1 4_1_2 4_2_2 5_1_1 10_2	PF 1.1.2. PF 1.1.3. PF 1.2.1. PF 1.4.2. PF 1.4.4. PF 1.5.1. PF 3.4.2.	PF 1.1. PF 1.2. PF 1.4. PF 1.5. PF 3.4.	PF 1. PF 3.
SKH_RQ7	SYS_RQ2_3	SYS_RQ2	1_2_2	PF 1.1.4.	PF 1.1.	PF 1.
SKH_RQ7	SYS_RQ2_4	SYS_RQ2	9_7	PF 3.3.7.	PF 3.3.	PF 3.
SKH_RQ4	SYS_RQ2_5	SYS_RQ2	/	/	/	/
SKH_RQ4	SYS_RQ2_6	SYS_RQ2	9_7	PF 3.3.7.	PF 3.3.	PF 3.
SKH_RQ7	SYS_RQ2_7	SYS_RQ2	9_2	PF 3.3.2.	PF 3.3.	PF 3.
SKH_RQ1	SYS_RQ3_1	SYS_RQ3	/	/	/	/

SKH_RQ1	SYS_RQ3_2	SYS_RQ3	2_1_2	PF 1.2.2.	PF 1.2.	PF 1.
SKH_RQ1	SYS_RQ3_3	SYS_RQ3	2_1_2	PF 1.2.2.	PF 1.2.	PF 1.
SKH_RQ1	SYS_RQ3_4	SYS_RQ3	2_2_1	PF 1.2.3.	PF 1.2.	PF 1.
SKH_RQ1	SYS_RQ3_5	SYS_RQ3	2_2_2 4_1_2 4_2_2 5_2_1 6_2_1	PF 1.2.4. PF 1.4.2. PF 1.4.4. PF 1.5.3. PF 1.6.3.	PF 1.2. PF 1.4. PF 1.5. PF 1.6.	PF 1.
SKH_RQ2	SYS_RQ3_6	SYS_RQ3	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ3_7	SYS_RQ3	3_1_2	PF 1.3.2.	PF 1.3.	PF 1.
SKH_RQ2	SYS_RQ3_8	SYS_RQ3	6_4_1 6_4_3 7_1	PF 1.6.7. PF 1.6.9. PF 3.1.1.	PF 1.6. PF 3.1.	PF 1. PF 3.
SKH_RQ1	SYS_RQ3_9	SYS_RQ3	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ3_10	SYS_RQ3	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ3_11	SYS_RQ3	8_4	PF 3.2.4.	PF 3.2.	PF 3.
SKH_RQ2	SYS_RQ3_12	SYS_RQ3	6_4_1 9_1 11_3	PF 1.6.7. PF 3.3.1. PF 3.5.3.	PF 1.6. PF 3.3. PF 3.5.	PF 1. PF 3.
SKH_RQ2	SYS_RQ3_13	SYS_RQ3	6_4_1 9_1 11_3 15_1 19_1	PF 1.6.7. PF 3.3.1. PF 3.5.3. PF 3.9.1. PF 3.13.1.	PF 1.6. PF 3.3. PF 3.5. PF 3.9. PF 3.13.	PF 1. PF 3.
SKH_RQ7	SYS_RQ3_14	SYS_RQ3	/	/	/	/
SKH_RQ1	SYS_RQ3_15	SYS_RQ3	17_1	PF 3.11.1.	PF 3.11.	PF 3.
SKH_RQ7	SYS_RQ3_16	SYS_RQ3	18_1 18_2 18_3 18_5	PF 3.12.1. PF 3.12.2. PF 3.12.3. PF 3.12.5.	PF 3.12.	PF 3.
SKH_RQ1	SYS_RQ3_17	SYS_RQ3	/	/	/	/
SKH_RQ1	SYS_RQ4_1	SYS_RQ4	6_2_1	PF 1.6.3.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ4_2	SYS_RQ4	6_2_2	PF 1.6.4.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ4_3	SYS_RQ4	6_3_1 6_4_1	PF 1.6.5. PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ4_4	SYS_RQ4	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ4_5	SYS_RQ4	6_4_1 13_1	PF 1.6.7. PF 3.7.1.	PF 1.6. PF 3.7.	PF 1. PF 3.
SKH_RQ2	SYS_RQ4_6	SYS_RQ4	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ7	SYS_RQ4_7	SYS_RQ4	6_4_1 13_1	PF 1.6.7. PF 3.7.1.	PF 1.6. PF 3.7.	PF 1. PF 3.
SKH_RQ2	SYS_RQ4_8	SYS_RQ4	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ2	SYS_RQ4_9	SYS_RQ4	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.

SKH_RQ6	SYS_RQ4_10	SYS_RQ4	6_4_2 14_4	PF 1.6.8. PF 3.8.4.	PF 1.6. PF 3.8.	PF 1. PF 3.
SKH_RQ6	SYS_RQ4_11	SYS_RQ4	6_4_2	PF 1.6.8.	PF 1.6.	PF 1.
SKH_RQ6	SYS_RQ4_12	SYS_RQ4	6_4_2	PF 1.6.8.	PF 1.6.	PF 1.
SKH_RQ6	SYS_RQ5_1	SYS_RQ5	6_4_1 6_4_3 7_1	PF 1.6.7. PF 1.6.9. PF 3.1.1.	PF 1.6. PF 3.1.	PF 1. PF 3.
SKH_RQ1	SYS_RQ5_2	SYS_RQ5	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ1	SYS_RQ5_3	SYS_RQ5	6_4_1	PF 1.6.7.	PF 1.6.	PF 1.
SKH_RQ6	SYS_RQ5_4	SYS_RQ5	6_4_3 7_1 9_8	PF 1.6.9. PF 3.1.1. PF 3.3.8.	PF 1.6. PF 3.1. PF 3.3.	PF 1. PF 3.
SKH_RQ1	SYS_RQ5_5	SYS_RQ5	7_2 10_1 10_2	PF 3.1.2. PF 3.4.1. PF 3.4.2.	PF 3.1. PF 3.4.	PF 3.
SKH_RQ2	SYS_RQ5_6	SYS_RQ5	7_2	PF 3.1.2.	PF 3.1.	PF 3.
SKH_RQ2	SYS_RQ5_7	SYS_RQ5	8_1 10_8 11_4 12_1 16_6	PF 3.2.1. PF 3.4.8. PF 3.5.4. PF 3.6.1. PF 3.10.6.	PF 3.2. PF 3.4. PF 3.5. PF 3.6. PF 3.10.	PF 3.
SKH_RQ5	SYS_RQ5_8	SYS_RQ5	8_3	PF 3.2.3.	PF 3.2.	PF 3.
SKH_RQ1	SYS_RQ5_9	SYS_RQ5	8_3 10_4	PF 3.2.3. PF 3.4.4.	PF 3.2. PF 3.4.	PF 3.
SKH_RQ1	SYS_RQ5_10	SYS_RQ5	8_4	PF 3.2.4.	PF 3.2.	PF 3.
SKH_RQ1	SYS_RQ5_11	SYS_RQ5	8_5	PF 3.2.5.	PF 3.2.	PF 3.
SKH_RQ6	SYS_RQ5_12	SYS_RQ5	9_3	PF 3.3.3.	PF 3.3.	PF 3.
SKH_RQ1	SYS_RQ5_13	SYS_RQ5	9_4	PF 3.3.4.	PF 3.3.	PF 3.
SKH_RQ5	SYS_RQ5_14	SYS_RQ5	9_5	PF 3.3.5.	PF 3.3.	PF 3.
SKH_RQ1	SYS_RQ5_15	SYS_RQ5	9_6	PF 3.3.6.	PF 3.3.	PF 3.
SKH_RQ5	SYS_RQ5_16	SYS_RQ5	9_8	PF 3.3.8.	PF 3.3.	PF 3.
SKH_RQ1	SYS_RQ5_17	SYS_RQ5	14_1	PF 3.8.1.	PF 3.8.	PF 3.
SKH_RQ2	SYS_RQ6_1	SYS_RQ6	6_4_1 9_1 11_3	PF 1.6.7. PF 3.3.1. PF 3.5.3.	PF 1.6. PF 3.3. PF 3.5.	PF 1. PF 3.
SKH_RQ2	SYS_RQ6_2	SYS_RQ6	6_4_1 9_1 11_3	PF 1.6.7. PF 3.3.1. PF 3.5.3.	PF 1.6. PF 3.3. PF 3.5.	PF 1. PF 3.
SKH_RQ2	SYS_RQ6_3	SYS_RQ6	6_4_1 9_1 11_1	PF 1.6.7. PF 3.3.1. PF 3.5.1.	PF 1.6. PF 3.3. PF 3.5.	PF 1. PF 3.
SKH_RQ2	SYS_RQ6_4	SYS_RQ6	6_4_1 9_1 11_3 15_1	PF 1.6.7. PF 3.3.1. PF 3.5.3. PF 3.9.1.	PF 1.6. PF 3.3. PF 3.5. PF 3.9.	PF 1. PF 3.

SKH_RQ2	SYS_RQ6_5	SYS_RQ6	6_4_1 9_1 11_3 15_1 19_1	PF 1.6.7. PF 3.3.1. PF 3.5.3. PF3.9.1. PF 3.13.1.	PF 1.6. PF 3.3. PF 3.5. PF 3.9. PF 3.13.	PF 1. PF 3.
SKH_RQ2	SYS_RQ6_6	SYS_RQ6	9_4	PF 3.3.4.	PF 3.3.	PF 3.
SKH_RQ2	SYS_RQ6_7	SYS_RQ6	9_8	PF 3.3.8.	PF 3.3.	PF 3.
SKH_RQ2	SYS_RQ6_8	SYS_RQ6	9_9	PF 3.3.9.	PF 3.3.	PF 3.
SKH_RQ2	SYS_RQ6_9	SYS_RQ6	10_6 10_7	PF 3.4.6. PF 3.4.7.	PF 3.4.	PF 3.
SKH_RQ2	SYS_RQ6_10	SYS_RQ6	11_1	PF 3.5.1.	PF 3.5.	PF 3.
SKH_RQ2	SYS_RQ6_11	SYS_RQ6	13_1	PF 3.7.1.	PF 3.7.	PF 3.
SKH_RQ2	SYS_RQ6_12	SYS_RQ6	13_1	PF 3.7.1.	PF 3.7.	PF 3.
SKH_RQ2	SYS_RQ6_13	SYS_RQ6	13_1	PF 3.7.1.	PF 3.7.	PF 3.
SKH_RQ2	SYS_RQ6_14	SYS_RQ6	13_2 15_4	PF 3.7.2. PF 3.9.4.	PF 3.7. PF 3.9.	PF 3.
SKH_RQ2	SYS_RQ6_15	SYS_RQ6	13_2	PF 3.7.2.	PF 3.7.	PF 3.
SKH_RQ5	SYS_RQ6_16	SYS_RQ6	14_4	PF 3.8.4.	PF 3.8.	PF 3.
SKH_RQ3	SYS_RQ6_17	SYS_RQ6	17_1	PF 3.11.1.	PF 3.11.	PF 3.
SKH_RQ3	SYS_RQ6_18	SYS_RQ6	17_1	PF 3.11.1	PF 3.11.	PF 3.
SKH_RQ3	SYS_RQ6_19	SYS_RQ6	17_2	PF 3.11.2.	PF 3.11.	PF 3.
SKH_RQ2	SYS_RQ6_20	SYS_RQ6	18_1 18_2 18_3 18_5	PF 3.12.1. PF 3.12.2. PF 3.12.3. PF 3.12.5.	PF 3.12.	PF 3.
SKH_RQ2	SYS_RQ6_21	SYS_RQ6	19_1	PF 3.13.1.	PF 3.13.	PF 3.

7.2. Appendix B

Steps ID	Corresponding ID_DIT process	Function (3)	Function (2)	Function (1)
STEP 1 - COMMUNICATE	1_1_1	PF 1.1.1.	PF 1.1.	PF 1.
STEP 2 - SEARCH/UNDERSTAND THE PROBLEM & ANALYSE CONSCIOUS AND UNCONSCIOUS	1_1_2 1_2_1	PF 1.1.2. PF 1.2.1.	PF 1.1. PF 1.2.	PF 1.
STEP 3 - IDENTIFY DESIGNING CONSTRAINTS	1_2_2	PF 1.1.4.	PF 1.1.	PF 1.
STEP 4 - EXCHANGE WITH THE INVOLVED STAKEHOLDERS	2_1_1	PF 1.2.1.	PF 1.2.	PF 1.
STEP 5 - FORMULATION OF POINT OF VIEW	2_1_2	PF 1.2.2.	PF 1.2.	PF 1.
STEP 6 - CONFRONT REQUIREMENTS, NEEDS AND CONSTRAINTS	2_2_1	PF 1.2.3.	PF 1.2.	PF 1.
STEP 7 - HYPOTHESIZE	2_2_2	PF 1.2.4.	PF 1.2.	PF 1.
STEP 8 - BRAINSTORM	3_1_1	PF 1.3.1.	PF 1.3.	PF 1.
STEP 9 - ORGANIZE/POOL IDEAS	3_1_2	PF 1.3.2.	PF 1.3.	PF 1.
STEP 10 - GENERATE SOLUTIONS	3_2_1	PF 1.3.3.	PF 1.3.	PF 1.
STEP 11 - VALIDATE AND DECIDE	3_2_2	PF 1.3.4.	PF 1.3.	PF 1.
STEP 12 - EXAMINATION OF THE FUNCTIONALITIES OF THE PRODUCT	4_1_1	PF 1.4.1.	PF 1.4.	PF 1.
STEP 13 - DRAW THE PRELIMINARY DRAFTS	4_2_1	PF 1.4.3.	PF 1.4.	PF 1.
STEP 14 - SELECT MATERIAL	4_1_2	PF 1.4.2.	PF 1.4.	PF 1.
STEP 15 - VALIDATE WITH THE USER	4_2_2	PF 1.4.4.	PF 1.4.	PF 1.
STEP 16 - MANUFACTURER REGISTRATION	N/A			
STEP 17 - PROCESSING PRODUCTION ORDER	7		PF 3.1.	PF 3.
STEP 18 - GENERATION OF THE BEST SUPPLY CHAIN CONFIGURATION	9		PF 3.3.	PF 3.
STEP 19 - SENDING PRODUCTION ORDER	9		PF 3.3.	PF 3.
STEP 20 - PRODUCTION	10		PF 3.4.	PF 3.

7.3. Appendix C

Steps ID	Corresponding ID_DIT process	Function (3)	Function (2)	Function (1)
STEP 1 - RECEIVE DESIGN AND SPECIFICATION	7_1	PF 3.1.1.	PF 3.1.	PF 3.
STEP 2 - VALIDATE DESIGN	7_2	PF 3.1.2.	PF 3.1.	PF 3.
STEP 3 - MATERIAL SELECTION	10_4	PF 3.4.4.	PF 3.4.	PF 3.
STEP 4 - MATERIAL PROCUREMENT	10_4	PF 3.4.4.	PF 3.4.	PF 3.
STEP 5 - PATH PLANNING	10_6	PF 3.4.6.	PF 3.4.	PF 3.
STEP 6 - 3D PRINTING & POST PROCESSING	10_6	PF 3.4.6.	PF 3.4.	PF 3.
STEP 7 - VALIDATION	10_8	PF 3.4.8.	PF 3.4.	PF 3.

7.4. Appendix D

Steps ID	Corresponding ID_DIT process	Function (3)	Function (2)	Function (1)
STEP 1 - RECEIVE DESIGN AND SPECIFICATION	7_1	PF 3.1.1.	PF 3.1.	PF 3.
STEP 2 - VALIDATION OF THE TECHNICAL SPECIFICATIONS OF MODEL TO FABRICATE	7_2	PF 3.1.2.	PF 3.1.	PF 3.
STEP 3 - IDENTIFY LOCAL SOURCES OF PLASTIC WASTE	9_2	PF 3.3.2.	PF 3.3.	PF 3.
STEP 4 - PUT IN PLACE SMART COLLECTOR	9_6	PF 3.3.6.	PF 3.3.	PF 3.
STEP 5 - TRANSPORT WASTE MATERIAL TO THE RECYCLING FACILITIES	9_9	PF 3.3.9.	PF 3.3.	PF 3.
STEP 6 - ADEQUATION AND PREPARATION OF THE MATERIAL, MATERIAL PRINTABILITY VERIFICATION	10_4	PF 3.4.4.	PF 3.4.	PF 3.
STEP 7 - PATH PLANNING-3D PRINTING	5_1_2	PF 1.5.2.	PF 1.5.	PF 1.
STEP 8 - POST PROCESSING	5_1_2	PF 1.5.2.	PF 1.5.	PF 1.
STEP 9 - TEST BY USE	6_1_1	PF 1.6.1.	PF 1.6.	PF 1.
STEP 10 - RE-DESIGN AND AFFINATION OF FABRICATION	5_2_2	PF 1.5.4.	PF 1.5.	PF 1.
STEP 11 - VALIDATION	6_1_2	PF 1.6.2.	PF 1.6.	PF 1.

7.5. Appendix E

Steps ID	Corresponding ID_DIT process	Function (3)	Function (2)	Function (1)
STEP 1 - COLLECT THE TRIGGERING USER'S NEEDS/IDEAS	1		PF 1.1.	PF 1.
STEP 2 - INVOLVE THE NECESSARY STAKEHOLDERS TO BRING THE RIGHT COMPETENCIES IN	2		PF 1.2.	PF 1.
STEP 3 - MATCH THE USER NEEDS WITH THE CONSTRAINTS OF THE SMARTIFICATION FUNCTIONALITIES AVAILABLE	3		PF 1.3.	PF 1.
STEP 4 - CHECK THE FEASIBILITY OF THE CONCEPT	4		PF 1.4.	PF 1.
STEP 5 - DESIGN IN DETAIL THE SMARTIFICATION SOLUTION (CO-CREATION PROCESS)	4_2		PF 1.4.	PF 1.
STEP 6 - PRODUCE PROTOTYPE	5_1_2	PF 1.5.2.	PF 1.5.	PF 1.
STEP 7 - TEST BY USE (LIVING LAB)	6_1_1	PF 1.6.1.	PF 1.6.	PF 1.
STEP 8 - REFINEMENT / FAULT SOLUTION / RE-ITERATION	5_2_2	PF 1.5.4.	PF 1.5.	PF 1.
STEP 9 - IDENTIFY SUPPLIERS	9_2	PF 3.3.2.	PF 3.3.	PF 3.
STEP 10 - RUNTIME USAGE OF THE SMARTIFICATION SERVICE/FURNITURE	6_1_2	PF 1.6.2.	PF 1.6.	PF 1.
STEP 11 - MESURE CUSTOMER SATISFACTION	N/A			