



FLASH-COMP

D7.1 – Methods and Tools for FLASH-COMP sustainability assessment

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Executive summary

The deliverable D7.1 titled “Methods and Tools for FLASH-COMP sustainability assessment” presents the assessment methodologies and tools designed by the consortium to evaluate the impacts of FLASH-COMP systems, developed in WP2-WP3-WP4, when implemented in the industrial testbeds at IAI and Azimut premises (WP6).

Leveraging on the process-flow and relevant KPIs identified for each use case in WP1 and thanks to the collaborative approach taken in task 7.1, the consortium achieved in establishing a unified framework that will streamline the process of KPI evaluation in the two use cases, IAI and Azimut.

Accordingly, the present deliverable depicts the work undertaken in task 7.1, the resulting holistic framework required for the evaluation of the multiple effects brought about by the various FLASH-COMP solutions in the upcoming work packages, and the next steps to use the proposed methods and tools in future. Specifically, the deliverable includes:

- I. A Zero-Defect Manufacturing Maturity assessment;
- II. An Efficiency and Eco-efficiency assessment;
- III. A Human Factor assessment.

Collectively, these models, methods and tools form the basis to evaluate the present (AS-IS) condition of each use case and the final results (TO-BE) after the experimentation of the FLASH-COMP solutions in the industrial testbeds at IAI and Azimut. Information collected in WP6 will feed the assessment tools proposed in the present deliverable to determine improvements, collect feedback as well as lessons learnt. These can be reused in future to facilitate a wider adoption of FLASH-COMP.



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1 Introduction

1.1 Scope of the deliverable

This deliverable D7.1 titled "Methods and tools for FLASH-COMP sustainability assessment" provides a comprehensive overview of the work accomplished in Task 7.1-Economic, Green & Waste Assessment Framework (KPIs), spanning from M12-M18 in the project timeline.

This deliverable encapsulates the collaborative efforts of the project consortium in defining an assessment framework which will be useful in the evaluation of the FLASH-COMP solutions when implemented in the industrial use cases.

The deliverable sets on presenting the primary assessment dimensions and their associated assessment methods with the overarching aim of substantiating the efficacy and sustainability of various FLASH-COMP solutions. Specifically, (i) Zero-Defect Maturity assessment framework developed by POLIMI, (ii) Efficiency and eco-efficiency assessment based on value stream mapping constructed by INEGI, and (iii) Human factor assessment developed by ESTIA. Insights and suggestions were also provided by the other partners involved in task 7.1, MSI, LORTEK, etc.

1.2 Relationship with other Work Packages and Deliverables

This deliverable leverages on previous work performed in the Work Package 1. The process of translating the project demands into evaluation techniques is critical because it allows for a systematic approach as shown in the Figure 1, to evaluate the outcomes and impacts of the solutions provided in the use cases.

Firstly, it allows for the evaluation of before-and-after project scenarios, giving a comparative analysis of performance metrics and key indicators prior to and following the adoption of FLASH-COMP solutions developed in WP 2-4.

Secondly, the structured assessment methodologies described in this deliverable are critical for identifying gaps and nuances that may arise during the project implementation phases in WP 5-6. By methodically analysing many aspects of the use cases, such as operational efficiency, environmental effect, and human factors, assessment tools can identify areas for improvement, and chances for optimisation.

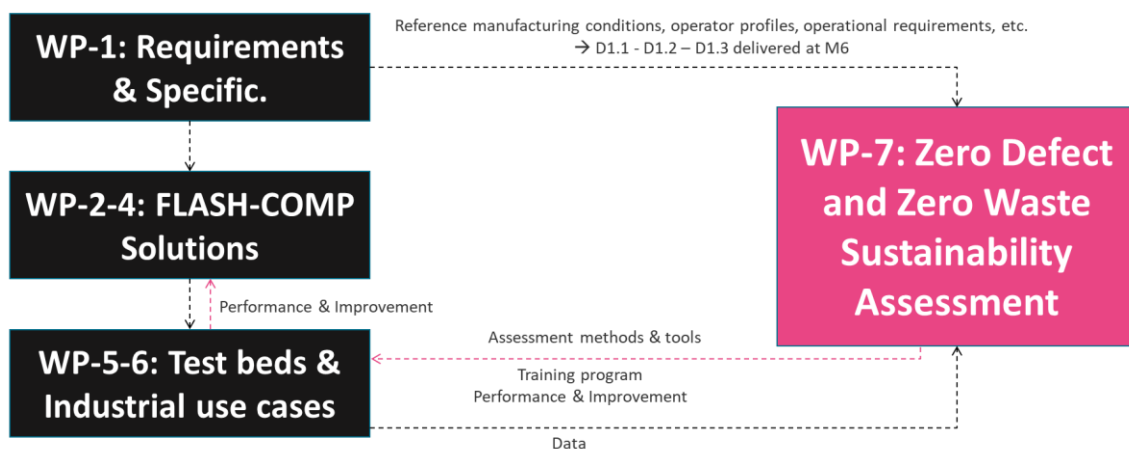


Figure 1 : Relationship among the Work Packages



1.3 Structure of the Document

Considering the scope of the deliverable, the remainder of the document is organized into three main sections.

Section 2 serves as an introductory overview, elucidating the approach and framework devised by the project consortium for the comprehensive sustainability assessment of the FLASH-COMP solutions. Following this overview, the document further delves into detailing the assessment methods and tools meticulously designed to facilitate the overall project assessment.

Within Section 3, enclosed are the structured breakdown of three key assessments, each targeting specific facets of digital innovation and sustainability within the context of FLASH-COMP:

- **Zero-Defect Maturity Assessment:** This method is aimed at evaluating the maturity level with respect to Zero-Defect Manufacturing.
- **Efficiency and Eco-efficiency Assessment:** This method intends to assess the performance of the process in several domains, namely operational, resources costs and environmental, providing a global overview of the process efficiency.
- **Human Factor Assessment:** This section focuses on human factors and their importance for the successful implementation and use of the FLASH-COMP solutions. This includes aspects like usability and skill development, which are necessary to establish a seamless workflow.

Finally, conclusions and next steps are briefly summarized in Section 4.

2 Overall approach and framework for FLASH-COMP sustainability assessment

2.1 The FLASH-COMP Framework

The FLASH-COMP Framework is constructed to map the different tasks and tools of the WP7, catering to different sustainability aspects. The framework is composed of three main levels of analysis and four main sustainability dimensions.

The three levels of analysis included in the framework resemble the three production planning levels commonly adopted in manufacturing companies:

1. The **Strategic level** is focused on the full system (plant, company, etc.) and oriented towards the long term.
2. The **Tactical level** is focused on the liquid resin infusion process and more oriented toward the medium term.
3. The **Operative level** is focused on the single experiment to be performed at the industrial testbeds and it is more oriented towards the short term.

The sustainability dimensions covered are the **economic, environmental, and social** ones. In addition, the **digital innovation** dimension is included due to its key importance for the FLASH-COMP project and the competitiveness of EU manufacturing companies.

In [Figure 2](#) the different WP7 assessment methods, tools and tasks are mapped into the FLASH-COMP's overall assessment framework.

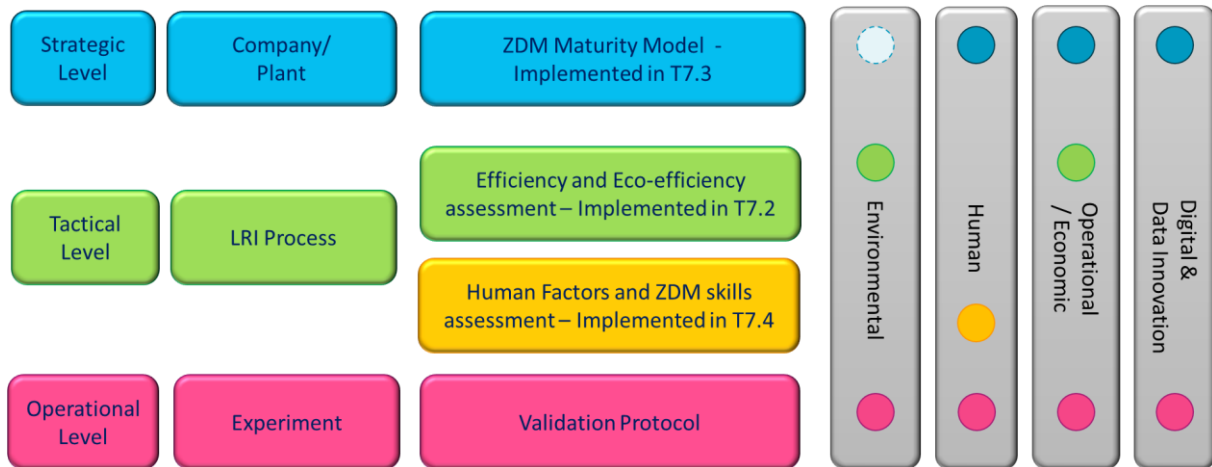


Figure 2: FLASH-COMP Framework

At the Strategic Level the focus is on setting the overall objectives and strategic direction towards Zero-Defect Manufacturing. Therefore, the Zero-Defect Maturity model was designed to capture all the socio-business-technical factors necessary to implement Zero-Defect Manufacturing in an industrial system.

The Tactical Level is more process oriented. The assessment, therefore, should depict the details of workflow encapsulating the machineries, data flow, and human skills required. The efficiency assessment based on value stream mapping and the human factor assessment were designed to particularly identify and address the holistic advancements in the liquid resin infusion process.

The operative level focuses on the experiments that will be performed in the two industrial use cases. The validation protocols specifically focus on the single experiment, comprising on the activities centred towards execution of the two industrial use cases in WP6.

3 Description of the FLASH-COMP methods and tools for sustainability assessment

3.1 Zero-Defect Maturity Assessment and Transformation Pathways

3.1.1 Development of the Zero-Defect Maturity Assessment

The Zero-Defect Maturity Assessment is based on the foundations of 6Ps digital maturity assessment and migration model developed by Polimi. It is based on 6 dimensions of analysis, which are Products, Process, Platform, People, Partnership and Performance. These dimensions are clustered into 2 categories: the technical pillar and the socio-business pillar, as represented in Figure 3.



Figure 3: The 6P digital maturity assessment and migration model

In task 7.1 the 6Ps model served as a starting point to organize the main dimensions to be evaluated in FLASH-COMP Zero-Defect Manufacturing maturity assessment. Leveraging on the 6Ps model, the design and development of the final Zero-Defect Maturity assessment was carried out by adopting the design science approach proposed by Kirmızı and Kocaoglu (2022) [1]. Significant activities were undertaken to meticulously draft a comprehensive framework to cater to the specific objectives and requirements of Zero-Defect Manufacturing and the FLASH-COMP project. These activities encompassed extensive research, and thorough analysis to ensure the effectiveness and relevance of the pillars and factors in the assessment tool. Moreover, through an iterative refinement and validation process, the final goal was to create a robust foundation that not only addresses the immediate needs of the project but also lays the groundwork for future adaptability and scalability.

3.1.1.1 Phase #1

Grey Literature analysis: Projects in the EU 4ZDM Cluster

This analysis centred around the 10 EU projects listed in the **4ZDM** Cluster (Figure 4). This analysis focused on complete evaluation and comparative assessment, delving into the multi-faceted landscape of projects covering several disciplines within the Manufacturing sector. These projects encompass a diverse set of concepts and approaches aimed at accomplishing the objective of zero-defects in manufacturing processes.

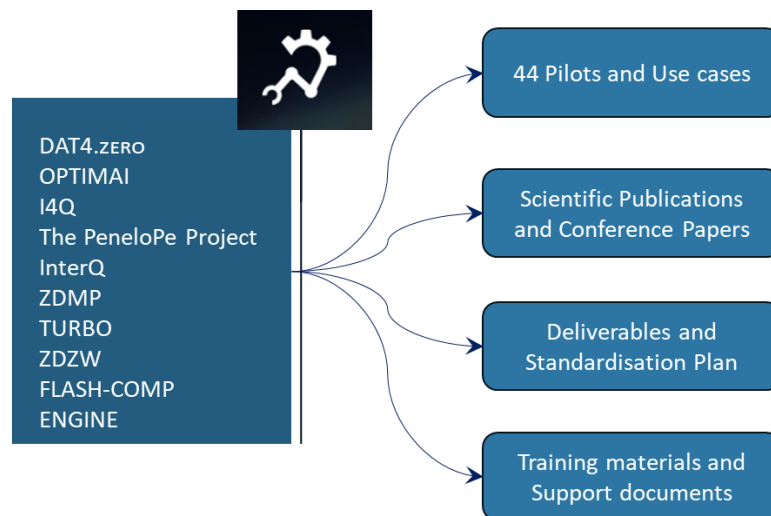


Figure 4: Projects in the EU 4ZDM Cluster

The landscape of Zero-Defect Manufacturing within the European Union (EU) is undergoing significant evolution, with a portfolio of 10 projects at varying stages of development. The commencement of these projects signifies the initiation of extensive research, development, and implementation efforts aimed at advancing the principles of Zero-Defect Manufacturing across diverse industrial domains.

The analysis brought out the relevance of robust data capturing capabilities in the models used in these initiatives. Effective data capture techniques are critical for gathering, storing, and processing the massive amounts of data produced by industrial processes, quality control systems, and supply chain operations. This includes deploying advanced sensing technologies, data gathering systems, and data management platforms to ensure that essential data points are captured on time and accurately. Furthermore, the observation from the analysis emphasises the delicate relationship between change management and the implementation of process modifications in the selected use cases. Change management approaches such as stakeholder engagement, communication strategies, training programmes, and performance monitoring are critical for navigating the intricacies of organisational transition.

As processes are rebuilt, technologies are introduced, and workflows are reconfigured to match with Zero-Defect Manufacturing principles, change management frameworks provide the structure and support required to ensure smooth transitions and reduce resistance to change. Therefore, understanding holistically the cultural, behavioural, and organisational implications is critical to the effective implementation and maintenance of Zero-Defect Manufacturing efforts.

Scientific Literature review

The literature review was conducted primarily, to analyse and identify readiness/maturity factors for Zero-Defect Manufacturing and secondly, towards understanding the prerequisites, obstacles, and facilitators of this transformative manufacturing paradigm. The systemically assembled set of academic literature (Figure 5), collectively address the research directions and investigations towards Process design, State-of-the-art perspectives and Organizational viewpoints concerning ZDM. Through this comprehensive analysis, the aim is to formulate the assessment methodology/ framework for the FLASH-COMP use cases on the journey to Zero-Defect Manufacturing, ultimately generating higher efficiency, quality, and competitiveness in the manufacturing industry.

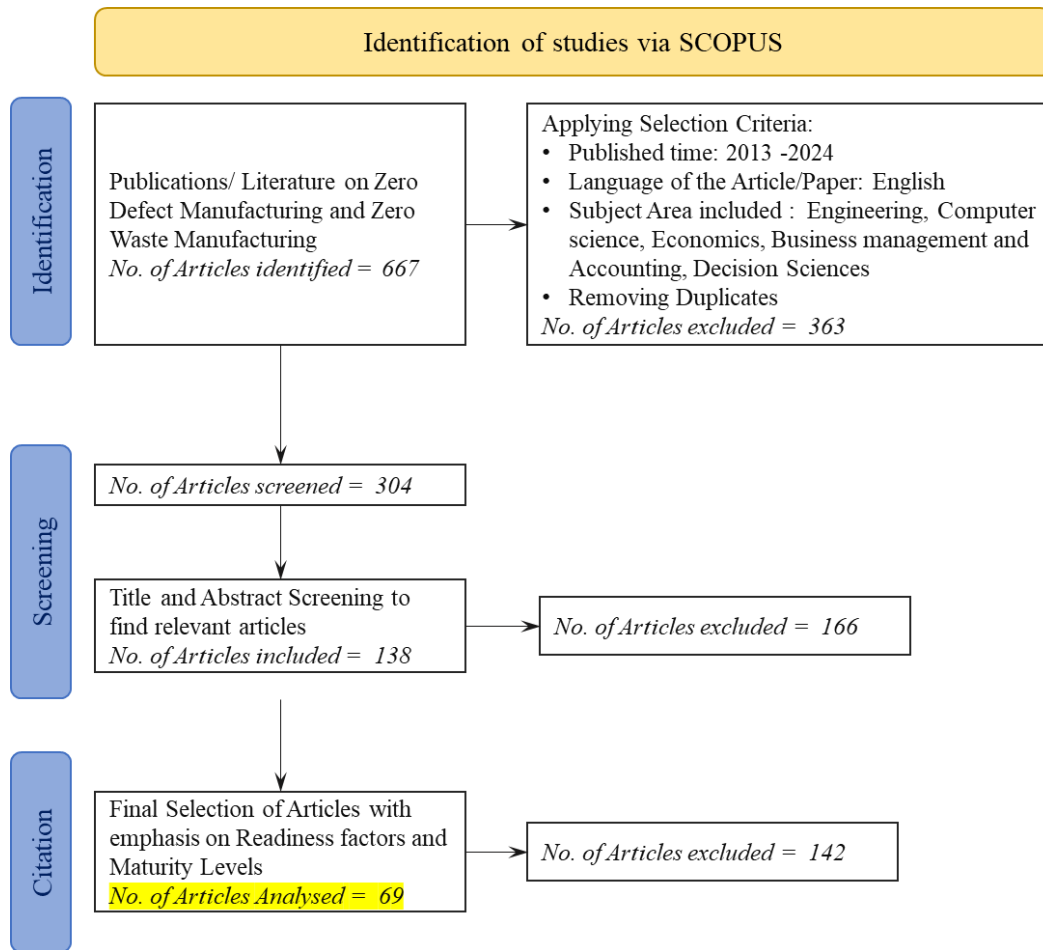


Figure 5: Identification of Academic Literature

The literature review presented in Figure 6, is a starting point in understanding the key aspects necessary to the development and implementation of Zero-Defect Manufacturing strategies, providing insights into a variety of topics such as technological advancements, organisational practices, human factors, regulatory frameworks, and supply chain dynamics.

At its core, the literature study aims to clarify the conceptual foundations of Zero-Defect Manufacturing, charting its history from old quality management systems to the current emphasis on proactive defect prevention and continuous improvement. In addition to theoretical foundations, the literature review examines empirical studies and industrial case studies to assess real-time applications of Zero-Defect Manufacturing processes. These case studies provide useful insights into the challenges, and lessons gained from organisations in a variety of industries, including automotive, aerospace, electronics, food, and pharmaceuticals. By combining these findings from various case studies, we have identified common patterns, best practices, and success factors that lead to the effective adoption and long-term application of Zero-Defect Manufacturing principles.

In order to comprehensively assess the factors influencing the successful implementation of Zero-Defect Manufacturing, we have carefully designed an evaluation matrix. This matrix serves as a structured framework for capturing and organizing relevant information essential for understanding and optimizing the implementation process.

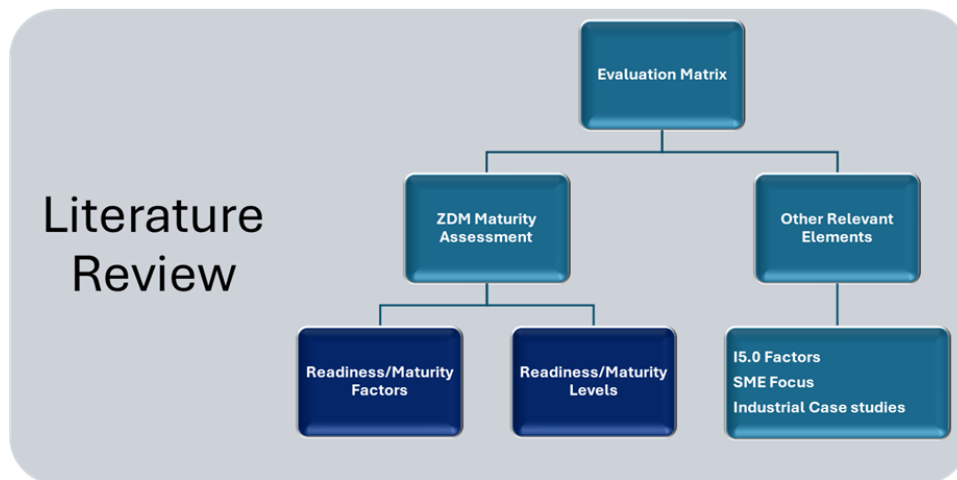


Figure 6: Overview of Literature Review

3.1.1.2 Phase #2

One of the primary focuses brought out from this analysis is the meticulous construction of questionnaires to analyse the organisations' current (AS-IS) and desired (TO-BE) states in Zero-Defect Manufacturing. This includes creating organised surveys or interview protocols to gather information about current operational practices, quality management systems, technical infrastructure, workforce capabilities, and strategic goals. In many cases, the assessment/surveys were carried out by third parties or experts in the field to get a complete understanding of the problems, opportunities, and readiness factors associated with the implementation of Zero-Defect Manufacturing principles by collecting data on numerous elements of the organisation in a methodical manner.

The literature review revealed quite a few examples demonstrating readiness and maturity levels across multiple parameters of Zero-Defect Manufacturing. All these models showcased similar levels of how organisations' skills and practices evolve over time in preparing to adopt Zero-Defect Manufacturing practices. These maturity levels usually progress from initial/very low level of awareness and ad hoc activities to completely optimised and institutionalised processes.

The Zero-Defect Framework comprising of the 6P Framework and the ZDM Questionnaire were developed through a collaborative process. After formulating the initial version of the matrix and questionnaire, we sought inputs and validation from the project partners. Their feedback helped refine and improve both the matrix and the questionnaire.

Following validation, project partners' suggestions for changes were carefully considered and integrated into the final versions of the matrix and questionnaire. This collaborative approach further guarantees that the framework appropriately reflects the FLASH-COMP objectives.

3.1.2 The Zero-Defect Maturity Assessment Model

3.1.2.1 ZDM Maturity Levels

The Figure 7 portrays the various Maturity/Readiness levels observed from the literature review.



Figure 7: Maturity/ Readiness Levels

Level 1 – Initial:

In the Initial stage, the organisation is beginning to steer towards the Zero-Defect Manufacturing practices. It implies that the organisation has little awareness or minimally acceptable effort in ZDM [2]. The efforts to address quality issues are mostly reactive and lack a strategic approach. Quality control processes are basic, focusing on discovering and addressing errors after they arise. There is little to no investment in technology or techniques designed to achieve zero faults.

Level 2 – Managed:

This stage of Maturing represents the realisation of the futuristic orientation of ZDM goals. This stage comprises of specific focus towards a standalone situation in which the ZDM strategy or methods are utilised. This stage indicates of the start of shift towards proactive measures aimed at identifying and addressing root causes of defects before they impact product quality. It is observed that this Maturity level predominantly focuses on finding alternative methods/tools in quality problem-solving.

Level 3 – Defined:

This stage indicates increased level of commitment to the principles of ZDM, with a focus on ensuring that every aspect of the manufacturing process contributes towards successful implementation of ZDM. Moreover, there is an improvement in the integration of various departments/processes towards quality control. There are clear, well-defined metrics to guide the employees, and an enabling top-management structure which further drives the quality culture.

Level 4 – Integrated:

At this stage, the organization fully integrates Zero-Defect Manufacturing (ZDM) processes into its culture and operations. Furthermore, this stage is characterized by commitment from both, every employee to uphold the highest standards of quality and the organisations' collective strive towards achieving zero defects in every product. This transition is further supported by the use of advanced technologies to optimize quality control processes, advanced analytics, machine learning algorithms, and real-time monitoring systems are utilised in analysing massive amounts of data generated throughout the manufacturing process, allowing for early detection of potential issues and predictive maintenance interventions to prevent defects from occurring.

Level 5 – Exploited:

This stage represents the organization's commitment to Zero-Defect Manufacturing goes beyond just compliance with industry norms—it becomes a driving force for transformative change and continuous improvement. Moreover, ZDM has become a part of the organization's culture, and becomes a source of long-term competitive advantage for the business, allowing it to stand out in the marketplace through greater quality, dependability, and customer satisfaction.



3.1.2.2 The ZDM Maturity Factors and related questionnaire

The Product Dimension

The Product Dimension centres around the product characteristics related to quality, sustainability and the aspects of “**smartness**” expected from the market. The study demonstrates the relevant features that define the product such as traceability, and diagnostic ability of the product. These factors are captured in the product with the use of cutting-edge technology.

There are seven different fields as shown in Figure 8 of analysis that are taken into account are related to: **Customisation**, that refers to level of customisation offered in the company; **Integration of Sensors and actuators** to understand if the product is equipped with the ability to be integrated with external devices; **Communication and Connectivity** to analyse how the product communicate with external environment; **Storage and Exchange of information** to measure if the product can facilitate data and information exchange; **Monitoring** to assess if the product exhibits self-monitoring capabilities; **Smart Traceability** to assess if the product is enabled to capture traceability information; **Smart Servicing** to measures if the organisation offers services related to products.

PRODUCT DIMENSION	LEVEL 1 INITIAL	LEVEL 2 MANAGED	LEVEL 3 DEFINED	LEVEL 4 INTEGRATED	LEVEL 5 EXPLOITED
CUSTOMISATION	No Customisation	Reactive	Standardised Procedures	Systemic Approach	Strategic
INTEGRATION OF SENSORS/ ACTUATORS	No use of Sensors/ Actuators	External sensors / actuators integrated	Sensor readiness processed by product	Sensors and other sources are analysed inside the product	Product able to respond autonomously to the ambient
COMMUNICATION/ CONNECTIVITY	No Communication / Connectivity	Low	Medium	High	Complete Communication / Connectivity
DATA STORAGE AND EXCHANGE OF INFORMATION	No functionalities	Possibility of individual ID	Product has passive data source	Product with data storage for autonomous information exchange	Data and information exchange are integral part
MONITORING	No Monitoring	Low	Medium	High	Full Monitoring
SMART TRACEABILITY	No Traceability	Low	Medium	High	Completely traceable
SMART SERVICING	No Services	Low	Medium	High	“Automated” services in place

Figure 8: PRODUCT Dimension

The Process Dimension

The Process Dimension has the main objective of assessing the level of maturity in the most relevant manufacturing processes in the Zero-Defect Manufacturing context. The Process Dimension is vast in covering all the facets of quality management, such as quality inspection, quality assurance, etc.



Several aspects of **quality management system** and **ZDM strategies** (Figure 9) are covered, from establishing a **quality control** system, to indication on levels of **inspection** taking place at the company, defining procedures to manage quality issues, **data analysis** on quality checks to assess the capturing and utilisation of available quality data collectively creating a process-driven culture that is critical for building a ZDM practice.

PROCESS DIMENSION	LEVEL 1 INITIAL	LEVEL 2 MANAGED	LEVEL 3 DEFINED	LEVEL 4 INTEGRATED	LEVEL 5 EXPLOITED
PROCESS MANAGEMENT	Ad-hoc processes	Most important processes are well-defined	Processes are well-defined and documented	Processes are managed as a system	Processes are managed proactively
QMS - QUALITY CONTROLS	QC at final tests	QC are executed at final tests and during the process	QC at final tests, during the process and acceptance stage	QC and reliability tests are executed	QC with active feedback system
QMS – LEVEL OF INSPECTION	Sample inspection	Sample inspection	100% inspection	100% inspection	100% inspection
QMS - PROCEDURES	No procedures	Reactive problem-solving procedures	Reactive problem-solving procedures	Proactive problem-solving procedures	Proactive problem-solving procedures
QMS - DATA ANALYSIS OF QUALITY CHECKS	No Data analysis	Irregularly managed	Periodically	Regularly and frequently	Real-time
RISK MANAGEMENT SYSTEM	No risk analysis	Product-oriented	Product and Process	Standard Methods (FMEA)	Standard Methods (FMEA)
STANDARDISED TOOL OR METHODS OF INTERVENTION	No Root-cause analysis	Based on experience	Standard Methods	Standard Methods and interventions	KAIZEN
ZDM STRATEGIES	Detection	Detection – Offline repair	Detection – Online repair	Prediction	Prediction - Prevention

Figure 9 : PROCESS Dimension

This Dimension also reports about the other important factors such as **Risk Analysis** to evaluate if there are control plans are in place to identify factors that affect the product quality; **Standardised tools or methods** – to assess the intervention actions in place to follow up with the quality issues that may arise during the quality inspection and/or during the processes; **ZDM Strategies** – represents the strategy employed at the company, and this is an important estimate as the ultimate progression of the FLASH-COMP project is aimed at implementing ‘Prediction-prevention’ strategy.

The Platform Dimension

The Platform Matrix in Figure 10, brings out the digital advancements the company could pursue in terms of building both the infrastructure and technological integration. The Platform Dimension holds together 10 factors contributing to the ZDM framework:

- I. **Inspection Instruments and Sensors;**
- II. **Asset Administration Shell (AAS);**
- III. **Vertical Interoperability of Data and Events;**
- IV. **Horizontal Interoperability of Data and Events;**
- V. **Industrial Data Platform;**



- VI. **Digital Twins;**
- VII. **Data Analytics;**
- VIII. **Human-Machine Interface;**
- IX. **Tracking System;**
- X. **Data Space.**

PLATFORM DIMENSION	LEVEL 1 INITIAL	LEVEL 2 MANAGED	LEVEL 3 DEFINED	LEVEL 4 INTEGRATED	LEVEL 5 EXPLOITED
INSPECTION INSTRUMENTS AND SENSORS	No Inspection instruments	Semi- Automated	Automated systems	Automated systems	Virtual Metrology
ASSET ADMINISTRATION SHELL (AAS)	No AAS	Basic AAS	Passive AAS	Reactive AAS	Proactive AAS
VERTICAL INTEROPERABILITY OF DATA AND EVENTS	No Vertical Interoperability	Low	Medium	High	Full Vertical Interoperability
INDUSTRIAL DATA PLATFORM	No Data Platform	Data Platform as basic repository	Well-defined Platform	Platform with Robust interoperability	Data Platform on well- defined policies, standards and procedures
DIGITAL TWIN	No DT	Introducing DT	DTs in Place	Future-oriented DTs	Advanced DTs
DATA ANALYTICS	No Data Analytics	Basic Analytics	Analytics in Place	Future-oriented Analytics	Advanced Analytics
HUMAN MACHINE INTERFACE	Paper based information	Static HMI	Fixed and/or mobile HMI	Advanced fixed and/or mobile HMI	Adaptive HMI
TRACKING SYSTEM	No Tracking System	Real-time tracking	Tracking of finished products	Tracking, localisation and monitoring of finished products	Tracking and status monitoring both in upstream and downstream
HORIZONTAL INTEROPERABILITY OF DATA AND EVENTS	No Horizontal Interoperability	Low	Medium	High	Full Horizontal Interoperability
DATA SPACE	No Data Space	Basic	Intermediate	Advanced	DS in place

Figure 10: PLATFORM Dimension

The People Dimension

The People Dimension presented in Figure 11 centres on the strategic and organisational factors which emerged as the most critical for successful implementation of ZDM. There are 5 factors such as **ZDM Strategy**: to measure how well the Zero-Defect Manufacturing has penetrated within the business strategy; **ZDM Culture and organisation**: to address the orientation of the organisation towards the ZDM mindset.

The **People management** factor is sub-classed into (i) **Skill management**: refers to the set of behaviour patterns required for effective task and function performance. It can be a motive, trait, skill, self-image, or knowledge[3] . Furthermore, Training for Quality 4.0 emphasises on the skills pertaining to Knowledge of Quality Assurance[4], information exchange, and tools for quality control[5]; (ii) **Employee engagement**: refers to the company capacity in fostering the “human-centred” innovations; and (iii) **Reward mechanisms**: refers to the creation of channels that enable employee participation and recognises employee contributions towards implementing ZDM strategies.



PEOPLE DIMENSION	LEVEL 1 INITIAL	LEVEL 2 MANAGED	LEVEL 3 DEFINED	LEVEL 4 INTEGRATED	LEVEL 5 EXPLOITED
ZDM STRATEGY	No ZDM	Some Initiatives	Strategy under development	Strategy is formalized	ZDM strategy in place
ZDM CULTURE AND ORGANISATION	No ZDM Culture and organisation	Some organisational orientation	Interests from top management	Organisational commitment to ZDM	Well-defined ZDM culture and roles
PEOPLE MANAGEMENT – SKILL MANAGEMENT	No People management practices	Some practices in place	Defined programmes to promote ZDM skills	Training programmes in place	Well-defined and regularised training programmes
PEOPLE MANAGEMENT – EMPLOYEE ENGAGEMENT	No People management practices	Some programmes in place	Initiation of consultation channels	Employees involved in development programmes	Employees are co-creators
PEOPLE MANAGEMENT – REWARD MECHANISM	No People management practices	Some initiatives in place	Initiation of appraisal programmes	Coherent practices in recognising ZDM-related ideas	Reward mechanisms related to performance on ZDM initiatives

Figure 11: PEOPLE Dimension

The Partnership Dimension

The Partnership Matrix (Figure 12) relates to the identification of the partners needed for transition towards ZDM and for achieving the desired business goals. It describes the workflows whose purpose is to support the transition towards more collaborative relationships with key stakeholders, in order to create strong and collaborative partnerships that are crucial for the successful transition.

Accordingly, partners included in the dimensions are: **Research and Innovation** - to measure the level of engagement that the firm has with these typologies of institutions; **Training and Education** – shows the company's involvement with external entities to provide specific ZDM knowledge; **IT Solution Providers** – presents the opportunities that could be exploited with proper partnerships especially with the IT solution providers as they represent the digital arena. The other prominent factors are **Supplier centeredness** and **Customer centeredness**, which refer to the accomplishments brought about by aggregating supplier/consumer inputs, in developing, and/or producing new products and services [6]; **Industrial Data sharing Agreements** to facilitate more collaboration in terms of data sharing schemes and frameworks towards developing an industrial data space to foster ZDM.



PARTNERSHIP DIMENSION	LEVEL 1 INITIAL	LEVEL 2 MANAGED	LEVEL 3 DEFINED	LEVEL 4 INTEGRATED	LEVEL 5 EXPLOITED
RESEARCH AND INNOVATION	No relationships	Limited Participation	Active involvement in joint projects	Collaboration in R&I projects	Systemic participation
TRAINING AND EDUCATION	No ZDM training	Occasional training programmes	Regularised training programmes	Planned learning programmes on ZDM	Widespread learning programmes and training on ZDM
IT SOLUTION PROVIDERS	No relationships	Basic digitalisation services	Collaborative in developing solutions	Reliable partnerships	Strategic partnership with game changing value
SUPPLIERS	No relationships	Transactional	Collaborative	Partnership	Strategic partnership
CUSTOMERS	No relationships	Transactional	Collaborative	Partnership	Strategic partnership
INDUSTRIAL DATA SHARING AGREEMENTS	No relationships	Only informal communication	Initial activities fostering data-sharing schemes	Bi- or Multi-lateral contractual frameworks	Formal industry agreements in place

Figure 12: PARTNERSHIP Dimension

The Performance Dimension

The Performance Dimension illustrated in Figure 13 aims at investigating the definition, monitoring, and interpretation of KPIs. The dimension is divided into 8 areas, namely: **Operational/Technical KPIs** to monitor the performances of machines and production activities such as OEE; **Economic KPIs** focused on economic and financial results such as Total Cost of Quality, Cost of Poor Quality, etc.; **Environmental** and **Social KPIs** to measure these performances and covering all the aspects of the triple bottom line; **Customer Satisfaction** that refers to the systems/tools adopted in monitoring customer satisfaction; **Product-Service Lifecycle** to assess to which extent and according to which criteria product's impacts are assessed along the lifecycle; **Supply Chain KPIs** to assess the modalities through which industries are able to measure the overall performances of their entire supply chain.



PERFORMANCE DIMENSION	LEVEL 1 INITIAL	LEVEL 2 MANAGED	LEVEL 3 DEFINED	LEVEL 4 INTEGRATED	LEVEL 5 EXPLOITED
OPERATIONAL	Performance not measured	Descriptive performance measurement	Diagnostic measurement	Predictive performance measurement	Prescriptive performance measurement
ECONOMIC	Performance not measured	Descriptive performance measurement	Diagnostic measurement	Predictive performance measurement	Prescriptive performance measurement
ENVIROMENTAL	Performance not measured	Descriptive performance measurement	Diagnostic measurement	Predictive performance measurement	Prescriptive performance measurement
SOCIAL	Performance not measured	Descriptive performance measurement	Diagnostic measurement	Predictive performance measurement	Prescriptive performance measurement
CUSTOMER SATISFACTION	Not monitored	Occasional monitoring	Periodical monitoring with traditional tools	Regularised monitoring of Customer satisfaction	Constant monitoring through established channels
PRODUCT-SERVICE LIFECYCLE	No Product LC management	A few Life-cycle aspects are included	Life-cycle Costing (LCC)	LCC and Environmental LCA	LCC, Environmental LCA and Social LCA
SUPPLY CHAIN	Performance not measured	Important attributes are monitored	Physical and Economical performance are monitored	Monitoring of Physical, Economical and Sustainability aspects	Initiatives to enable continuous improvement of all the aspects
DATA PERFORMANCE	Data quality not understood	Evaluation against Generic standards	Establishing detailed measurement attributes	Proactive monitoring of Data quality	Evidence-based monitoring of Data quality

Figure 13: PERFORMANCE Dimension

3.1.2.3 The ZDM maturity assessment and Transformation Journey

The ZDM maturity assessment aims at helping companies to generate strategies for approaching and moving towards ZDM and it serves as a starting point and a basis for new ideas and roadmaps. It helps enterprises to highlight the main gaps to be filled with a digital transformation process since it is required to evaluate both the current and the expected level, for each pillar and sub-dimension.

The method is based on five main steps:

1. **Set-up of a team bringing together different organizational areas:** the identification of the staff able to detect the main gaps in the several dimensions of the company is fundamental to drive the company toward the zero-defect transformation.
2. **Identification of the AS-IS profile of the manufacturing enterprise:** the manufacturing enterprise's strategy, competitive strengths and weaknesses, etc. must be analysed. Then, its current profile must be mapped into each dimension and development stage.
3. **Definition of the target TO-BE profile of the manufacturing enterprise:** the future vision and desired profile of the manufacturing enterprise must be defined considering the links to the business and competitive priorities, and thus mapped onto each dimension and development stage.
4. **Identification of actions, feasibility, and prioritization:** this step is about identifying the actions needed to migrate from the AS-IS to the TO-BE and considering the links to the business strategy as well as benefits and costs, risks and dependencies, evaluating to what extent investments are justified and what actions should be prioritized.
5. **Development of the migration plan towards Zero-Defect Manufacturing:** finally, the



migration plan is developed. To this respect, different approaches can be adopted. Often, the most successful is to focus on simple actions with short-term payoffs at first (quick wins) before implementing more complex and long-term projects.

3.1.3 Next Steps to implement the ZDM maturity assessment in FLASH-COMP

As explained above the assessment is based on a set of matrixes and a questionnaire comprising of precisely authored questions across the 6 dimensions. These questions will be evaluated on the maturity levels, firstly to identify the AS-IS situation, the expected TO-BE situation and finally the TO-BE situation at the end of the project. Both the industrial use cases - IAI and Azimut – will be evaluated throughout the FLASH-COMP project tracking the improvements along this timeline.

The assessment will be compiled through an online survey format using the Qualtrics application. The online assessment tool will be created in Task 7.3. These compilations will be designed to enable semi-automatic assessment of the maturity level upon reception of the online survey. Upon accessing the survey, the respondent will be introduced by a welcome page that explains the purpose of the questionnaire within the FLASH-COMP project, followed by a page of biographical and sectoral data of the compiler's company. Then, the respondent will be presented the six sections of questions (product, process, platform, people, partnerships, performances); the questionnaire gives the option of skipping sections that are not applicable to the context of the use case. Each question, corresponding to a dimension of analysis, will have 5 levels of response, corresponding to increasing levels of maturity; for each question there will be the “Not Applicable” option in case the question is not applicable to the use case. The tool will also give the possibility of saving the answers and resuming them later, in case more than one colleague, each with his or her own expertise, will be needed for its compilation.

When the compilation is complete, the compiler will save the results which will be received by POLIMI's analysts on a dedicated Qualtrics Data & Analysis page. Following the online compilation, one-on-one interviews with the compilers will be performed during Task 7.3. Conducting the interviews is necessary to establish a proper interpretive framework with respect to the industrial companies' use cases, to understand if there were any difficulties in compilation, resolve any interpretive doubts, validate the responses, and carry out ensemble considerations, between the companies' leaders and POLIMI, on the interpretation of the survey results in relation to the use cases and experiments in industrial testbeds.

3.2 Efficiency and Eco-Efficiency Assessment

3.2.1 Methodology Overview

To conduct efficiency and eco-efficiency assessment, a methodology that involves multiple tools will be implemented following the diagram illustrated in [Figure 14](#). With data from the process flow analysis, conducted in WP1, and a VA (Value Added) and NVA (Non-Value Added) assessment, the production process and resource efficiency will be assessed, using the Multi-layer Stream Mapping (MSM) methodology. Furthermore, the eco-efficiency will be assessed using costs and Life Cycle Inventory (LCI) data. The implementation of this methodology intends to assess the performance of the process in several domains, namely operational, resources costs and environmental, providing a global overview of the process efficiency.

Considering that the main goal of this project is the implementation of innovative technological solutions that allow to reduce product defects in manufacturing processes, this methodology will be



implemented in two steps. In a first stage, a baseline will be conducted to assess the current performance of the process, and, in a second stage, the final process performance assessment will be performed after the implementation of the FLASHCOMP solutions. In that sense, the added value of the FLASHCOMP project will be assessed, being possible to demonstrate its efficiency in order to achieve zero wastes and zero defects.

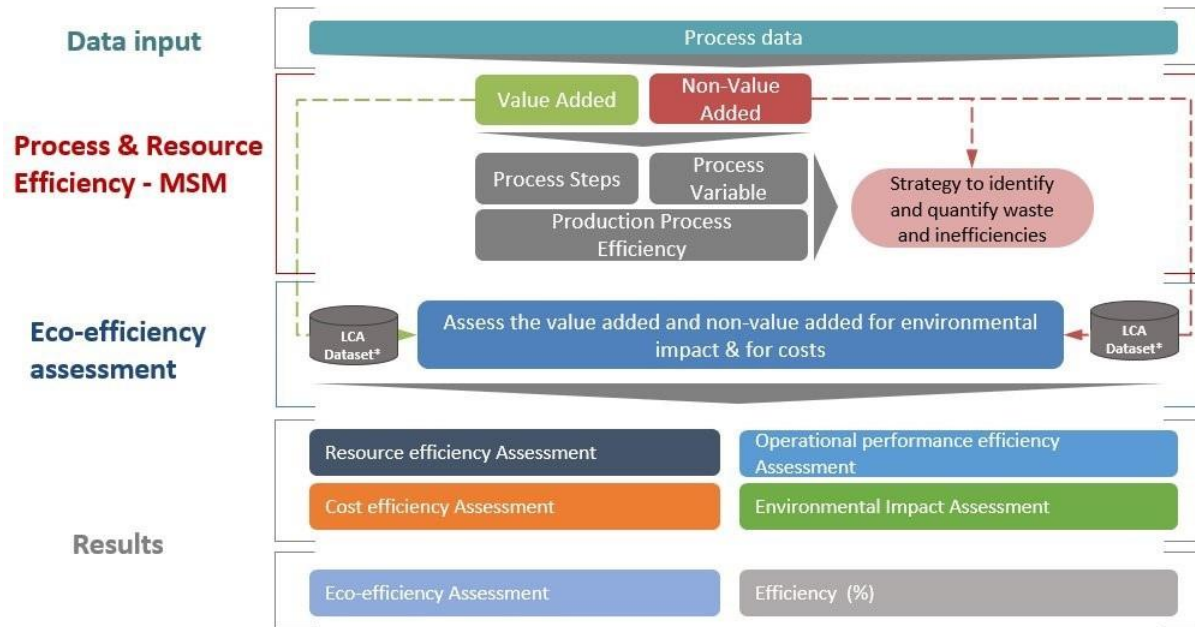


Figure 14: Methodology overview

In this project, the overall performance assessment will be carried out for two use cases, representing two relevant industrial sectors, namely: ship building and aeronautical sectors, and covering different materials, part sizes and monitoring/inspection challenges. Moreover, considering that an experimental setup will be implemented at INEGI in order to test the FLASH-COMP technologies in control conditions in laboratory, before being tested in use cases, the performance assessment will also be conducted for the test bed.

3.2.2 Process Assessment – Multi-Layer Value Stream Mapping tool

The MSM tool was designed by INEGI with the objective to map a given system, in terms of its efficiency, which can be materialized in the form of a production process or service process. It is intended to be a tool not only for analytical mapping but also to support decision-making in terms of operational management, when implemented in the form of software that allows for more agility in data input and processing of results [7].

The results of the MSM tool are presented in a dashboard, which visually resembles a matrix ($n \times m$), where ' n ' corresponds to the number of Key Performance Indicators (KPIs) analysed for the system under study and ' m ' to the number of phases in the system processes for the production under study, as illustrated in Figure 15.

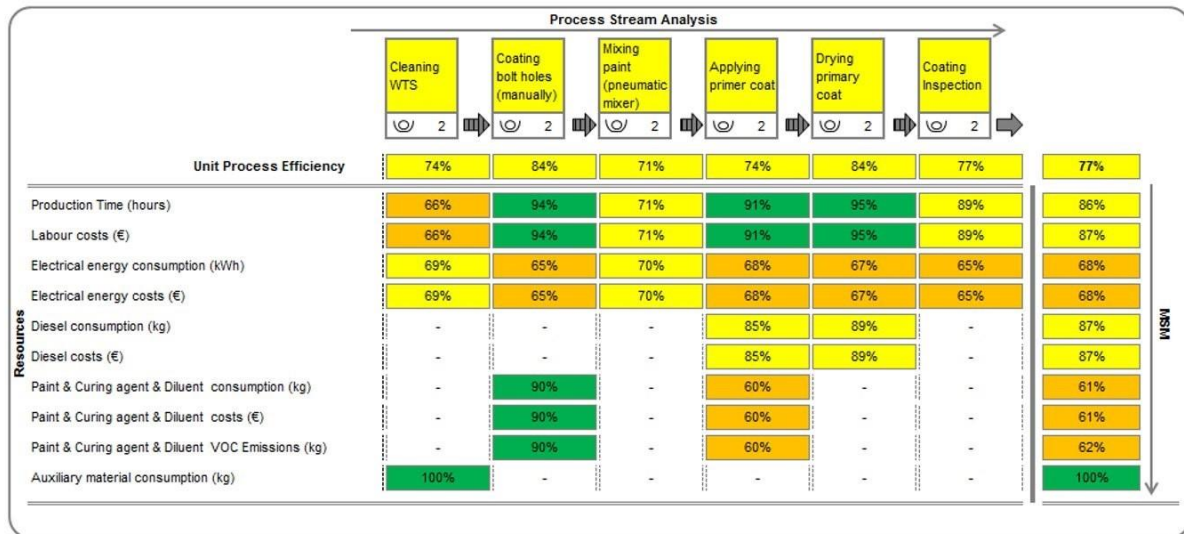


Figure 15: Example of the structure of the MSM tool

To deploy the MSM tool, the following steps must be performed:

1. Identification of the system's boundaries and process phases. In this step, the chosen process must be broken down into phases and tasks/activities, ideally with participation of the production team (operators, process manager, etc.) to identify the relevant variables to evaluate;
2. Definition of the types of KPIs to be used for each of the previously identified variables (always ranging from 0 to 100 %);
3. Identification of the Value Added (VA) and Non-Value Added (NVA) activities that compose each process phase, when possible;
4. Definition of reference values (expected values, historic results, industry standards, etc.) for KPIs that can't be measured by VA and NVA segregation;
5. Analysis of the results, identifying the most inefficient variables/stages, prioritizing and studying improvement actions;
6. Implementation of improvement actions and assessment of gains achieved in terms of efficiency and cost reduction.

Employing visual management practices, the MSM tool presents the results in a dashboard with a colour scale associated with a range of efficiencies, as depicted in Figure 16.

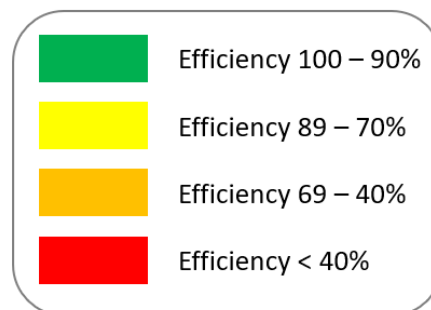


Figure 16: Colour scale legend of the MSM tool



3.2.3 Eco-Efficiency Assessment

Eco-efficiency is a concept that seeks to elucidate the connection between the economic benefits of a particular activity or production process and its corresponding environmental impacts, directly tied to sustainable development. In essence, eco-efficiency evaluates the correlation between environmental and economic advancements in activities, highlighting sustainability aspects that yield greater value through reduced material and energy inputs and emissions. Therefore, eco-efficiency analysis integrates the costs derived from cost analysis with the assessment of environmental impacts.

a. *Environmental Impact Assessment*

The environmental assessment offers a systematic approach to evaluate the environmental impacts associated with the resin infusion process. Central to this assessment is the compilation of a comprehensive Life Cycle Inventory, which entails cataloguing all inputs and outputs associated with each phase of the process. This involves gathering data on resource consumption, energy usage, waste generation, and other relevant factors.

Following the compilation of the Life Cycle Inventory (LCI), an impact assessment is conducted to translate the collected data into quantifiable environmental impacts. Impact categories may include but are not limited to, resource depletion, human health, global warming potential, acidification and eutrophication. The collected information was processed in SimaPro v9.2.0.2 software using the ReCiPe 2016 method to quantify the environmental impacts of the input data and the information inherent to the extractive and transformative processes in the Ecoinvent 3.7.1 database.

b. *Cost Assessment*

The process cost analysis provides insights into all expenses associated with the resin infusion process, encompassing operational and running costs. These costs include labour, materials and energy expenditures. Labour costs are related to the time required for a worker to complete a task, a crucial factor for accurate cost allocation. The process cost analysis is correlated with process flow analysis, offering a comprehensive understanding of the cost dynamics within the system.

By conducting this analysis, we can identify the operations and process steps where costs are notably higher. This identification enables the formulation of strategies aimed at mitigating these costs, wherever feasible, optimizing cost efficiency.

3.2.4 Use case Tool Implementation

a. *Process evaluation (phases)*

Following the development of the infusion process flowchart, conducted in WP1, and the definition of the activities that comprise each phase of the process, each company selected the phases that shall be focused in the efficiency and eco-efficiency assessments, based on the impact that FLASH-COMP solutions will have on the process. Therefore, the specific process phases that will be modified and enhanced by the new FLASH-COMP technologies were selected. Besides, all the phases that will suffer the impact of these innovative solutions were also considered. Furthermore, the activities constituting each selected phase were also examined to identify the ones that add value (VA) to the product and the ones that do not add value (NVA). The resulting selection is depicted in Figure 17 and Figure 18, corresponding to IAI and Azimut processes phases, respectively.

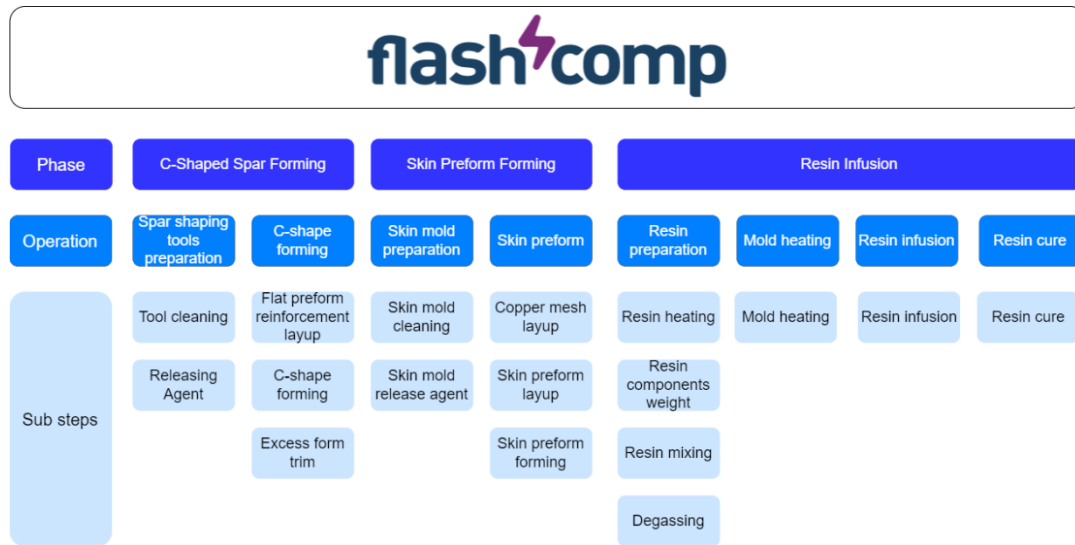


Figure 17: IAI Process Phases

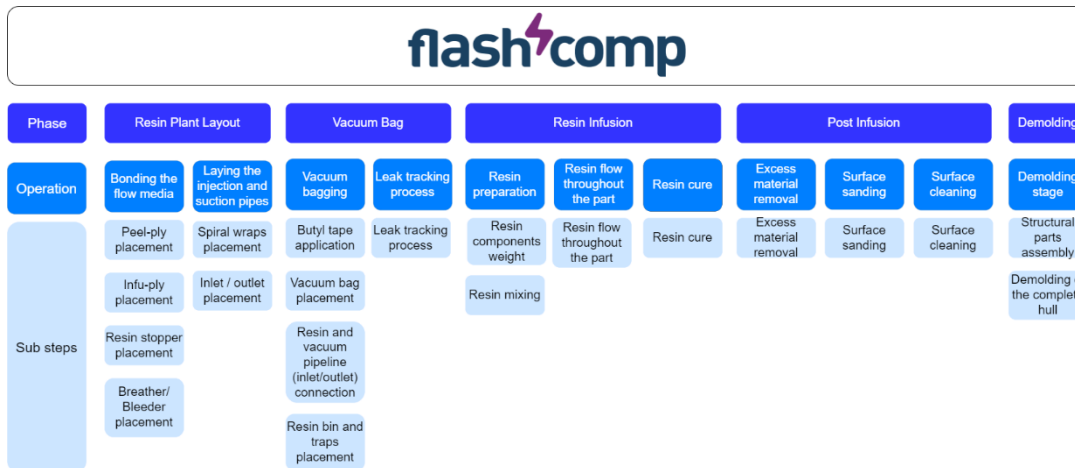


Figure 18: Azimut Process Phases

b. KPI definition

The KPIs allow to assess whether the most important/critical performance variables are within expected values and to evaluate the performance of an organization or a specific process. In the case of the MSM methodology, since the KPIs return values as percentages, always ranging from 0 to 100 % (to avoid distortions in aggregate efficiency values), it becomes intuitive to analyse the system's efficiency results. Furthermore, another crucial aspect in defining KPIs for the MSM tool is the requirement that all indicators must be defined with the aim of being maximized, in other words, the goal should always be to reach 100 %.



With that, the list of KPIs was defined taking into consideration the indicators identified in WP1, for each use case, and literature review. In addition, the list was validated by the respective companies and presented to the remaining members of WP7, for further feedback. The defined KPIs for both IAI and Azimut are presented in [Figure 19](#) and [Figure 20](#), respectively.

c. Final Tool

With all steps of the methodology identified, the data necessary for the efficiency assessment will be collected, and the results will be presented in an MSM Dashboard, as presented in [Figure 19](#) and [Figure 20](#), for IAI and Azimut, respectively.

As previously, mentioned, this tool will be implemented in two different phases of the project. A first stage prior the implementation of the FLASH-COMP solutions and a second stage after the introduction of the innovative technologies into the above-mentioned manufacturing processes.

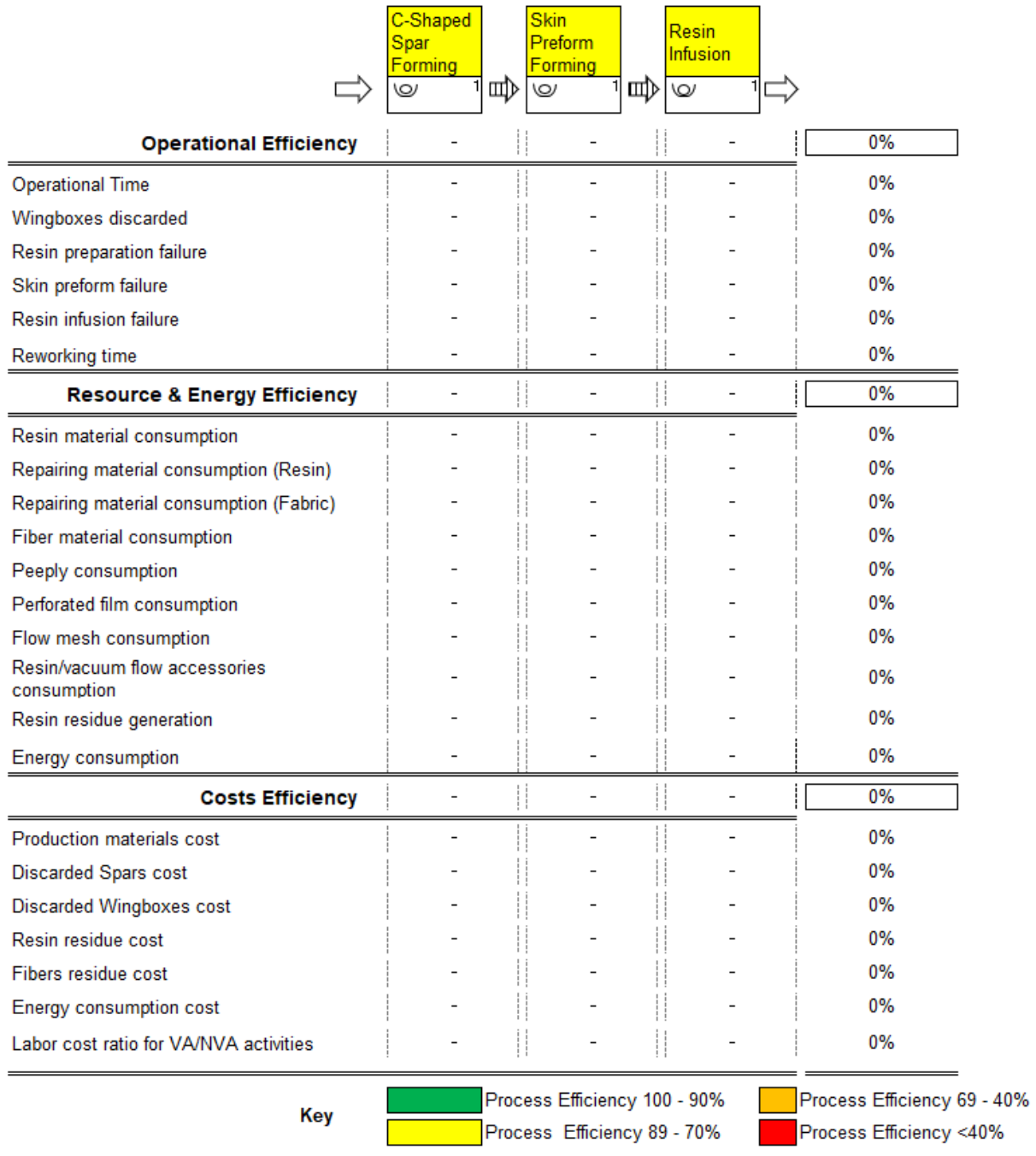


Figure 19: Final Tool - IAI

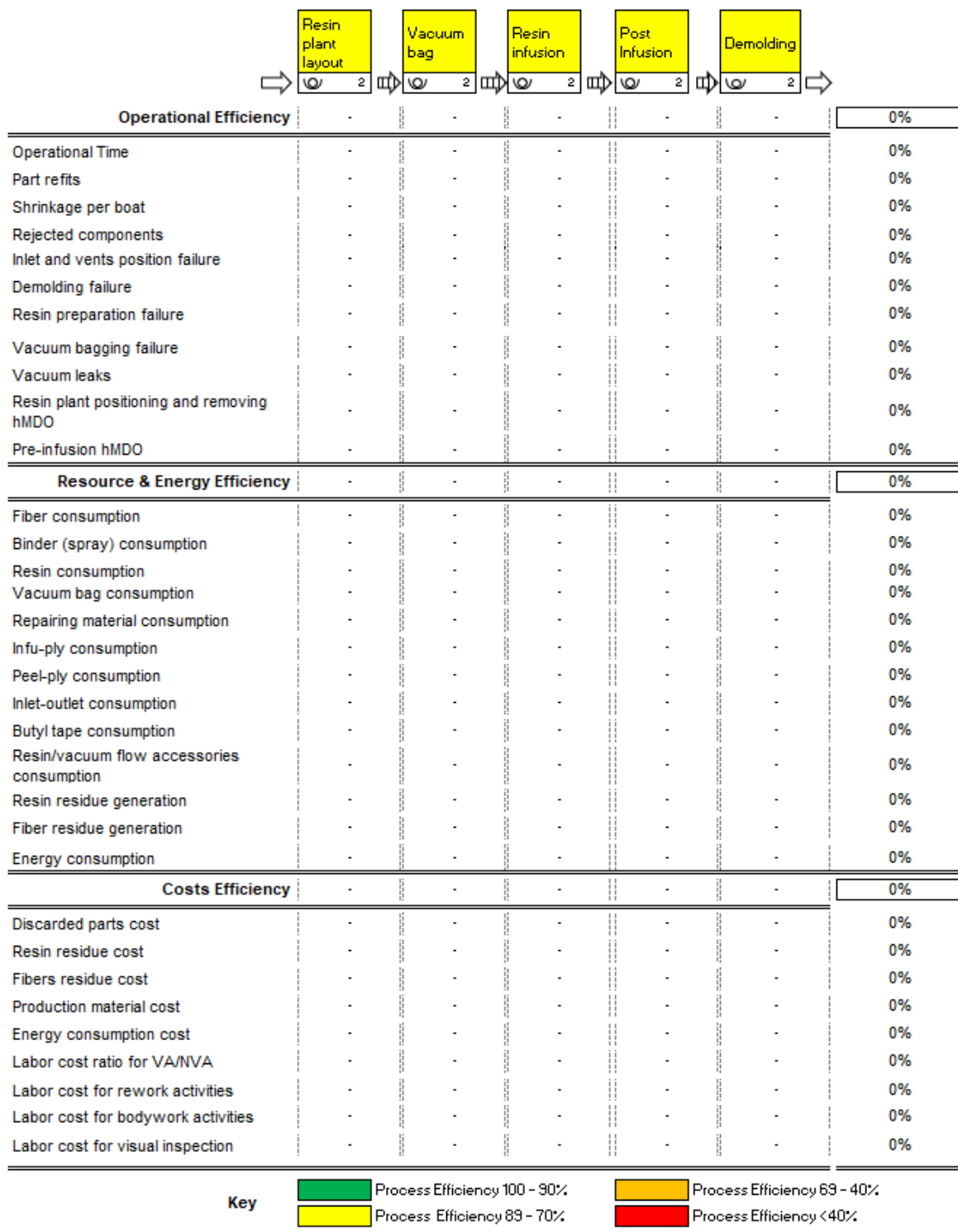


Figure 20: Final Tool – Azimut



3.2.5 Testbed Implementation

The methodology will also be deployed to assess the physical testbed, placed at INEGI's facilities, which will be used for the testing of glass fibre-based composites in medium-size coupons, to start adapting the solution to Azimut's use case.

a. Process evaluation (phases) and KPI definition

The focused process steps were defined by the technical team that will conduct the simulation of Azimut's resin infusion process, at INEGI. As for the list of Key Performance Indicators, they were defined taking into consideration the feedback received from the pilot company and the team involved in the development of the physical testbed. The KPIs are divided into three categories: Operational, Resources & Energy, and Costs. First column of Figure 18 presents the KPIs, along with their respective categories and the selected process steps.

b. Final Tool

Similarly, as conducted for the use cases, the data necessary for the efficiency assessment of the testbed will be collected and the results, for the selected process phases, will be presented in an MSM Dashboard, as presented in Figure 21.

	Mold Preparation	Gelcoat Preparation and Application	Manual Lamination of Reinforcements	Layup Dry Reinforcements	Resin Plant Layout	Vacuum Bag	Resin Infusion	
	⇒ 2	⇒ 2	⇒ 2	⇒ 2	⇒ 2	⇒ 2	⇒ 2	⇒
Operational Efficiency	-	-	-	-	-	-	-	0%
Operational Time	-	-	-	-	-	-	-	0%
Part refits	-	-	-	-	-	-	-	0%
Rejected components	-	-	-	-	-	-	-	0%
Mold preparation failure	-	-	-	-	-	-	-	0%
Inlet and vents position failure	-	-	-	-	-	-	-	0%
Resin preparation failure	-	-	-	-	-	-	-	0%
Vacuum bagging failure	-	-	-	-	-	-	-	0%
Skin coating failure	-	-	-	-	-	-	-	0%
Vacuum leaks	-	-	-	-	-	-	-	0%
Resin plant positioning and removing hMDO	-	-	-	-	-	-	-	0%
Resource & Energy Efficiency	-	-	-	-	-	-	-	0%
Gelcoat consumption	-	-	-	-	-	-	-	0%
Fiber consumption	-	-	-	-	-	-	-	0%
Binder (spray) consumption	-	-	-	-	-	-	-	0%
Resin consumption	-	-	-	-	-	-	-	0%
Core material consumption	-	-	-	-	-	-	-	0%
Vacuum bag consumption	-	-	-	-	-	-	-	0%
Cleaning material consumption	-	-	-	-	-	-	-	0%
Infu-ply consumption	-	-	-	-	-	-	-	0%
Peel-ply consumption	-	-	-	-	-	-	-	0%
Butyl tape consumption	-	-	-	-	-	-	-	0%
Resin/vacuum flow accessories consumption	-	-	-	-	-	-	-	0%
Resin residue generation	-	-	-	-	-	-	-	0%
Fiber residue generation	-	-	-	-	-	-	-	0%
Energy consumption	-	-	-	-	-	-	-	0%
Costs Efficiency	-	-	-	-	-	-	-	0%
Discarded parts cost	-	-	-	-	-	-	-	0%
Resin residue cost	-	-	-	-	-	-	-	0%
Fibers residue cost	-	-	-	-	-	-	-	0%
Production material cost	-	-	-	-	-	-	-	0%
Energy consumption cost	-	-	-	-	-	-	-	0%

Key	Process Efficiency 100 - 90%	Process Efficiency 69 - 40%
	Process Efficiency 89 - 70%	Process Efficiency <40%

Figure 21: Final Tool – Testbed



3.2.6 Next Steps

- Data collection:

The data collection step entails gathering relevant information for the selected KPIs associated with each process phase. This process will involve the retrieval of quantitative and qualitative data through various means, including direct observation, measurement, interviews, and existing documentation. The collected data will serve as the foundation for assessing the current performance of each process step and the formulation of the baseline.

Data will be collected for the selected process phases of both Azimut and IAI, as well as for the physical testbed in INEGI's facilities.

- Baseline formulation

The baseline step encompasses defining the initial state of the process under evaluation, including the baseline values for the selected KPIs. By establishing the baseline, it will be created a benchmark for gauging the effectiveness of the implementation of FLASH-COMP's solution. The operational efficiency and eco-efficiency baseline will be presented in an MSM scorecard fashion.

- Data collection after implementation of FLASH-COMP's solutions

Following the implementation of the FLASH-COMP's solutions, data collection will resume to capture the impact of the interventions on the selected KPIs for each process step. This phase will involve assessing how the implemented solutions have influenced the performance indicators, identifying any improvements or deviations from the baseline, and evaluating the overall effectiveness of the interventions in achieving the project's objectives.

- **22**Final assessment

In the final assessment step, the data collected will be synthesized and the efficiency performance will be analysed for the established KPIs. This comprehensive evaluation will enable us to draw conclusions regarding the efficacy of the interventions, identify successful strategies, and pinpoint areas requiring further attention or refinement. The final assessment serves as a critical step in determining the project's overall impact and informing future decision-making processes.

Like previously, the efficiency and eco-efficiency baseline will be presented in an MSM scorecard fashion.

- Comparative analysis

The comparative analysis step will involve the comparison of the formulated baseline with the final assessment. By conducting a comparative analysis, we will gain insights into the effectiveness of the interventions, identify patterns of change, and discern areas of success or challenge. This analysis will facilitate a deeper understanding of the project's results and help stakeholders make informed decisions regarding future initiatives and improvements.



3.3 Human Factor assessment methods and tools

3.3.1 System Design

KPI N°1: Expert analysis

The expert analysis method consists of **evaluating the design** of an interface based on **heuristic**. We will use the Ergonomic criteria for the evaluation of Human-Computer Interfaces (HMI), defined by Bastien & Scapin[8]. These heuristics are based on 8 criteria:

- Guidance,
- Workload,
- Explicit control,
- Adaptability,
- Error management,
- Consistency,
- Significance of codes,
- Compatibility.

The expert analysis will take place when **developers finish the 1st version** of the FLASH-COMP solution. They will pass it to human factors specialists of ESTIA, who will realize the expert analysis, and human factors recommendations in purpose.

Goals: Identify, during the design of the solution, **usability problems**, classify them according to **priority** (critical, medium, minor) (Table 1), and **define design recommendations**.

KPI Evaluation: Usability problems identified during the system design should not be identified during the system evaluation step.

Table 1: Example of HMI evaluation deliverable

Criteria		Guidance	Workload	Explicit control	Adaptability
Respect of the criteria		70%	60%	90%	70%
Number of problems	Critical	1	2	0	0
	Medium	2	2	0	4
	Minor	1	3	1	1

Criteria		Error Management	Consistency	Significance of codes	Compatibility
Respect of the criteria		90%	70%	100%	50%
Number of problems	Critical	0	1	0	3
	Medium	1	1	0	4
	Minor	0	3	0	1



3.3.2 System Evaluation

KPI N°2: Usability test

The usability testing method consists of **evaluating the usability of a product**. It refers to evaluating a product or service by testing it **with representative users**. Typically, during a test, participants will try to complete typical tasks while observers watch, listen, and take notes. No specific tools are needed to run user tests. Tests will be carried out during operator training.

The precise objects of the evaluation will be determined later, after the 1st version of the solution put on use, for example we could evaluate:

- Information disposition
- Frequency, utility & quality of errors messages or feed-backs
- Navigation system
- Learning
- Etc.

Goals: To **identify** any **usability problems** and classify them according to **priority** (critical, medium, minor). In the end, ergonomic **recommendations** will be proposed to improve usability.

KPI Evaluation:

- 100% of ergonomic problems identified as critical must be addressed.
- 100% of the interfaces in the FLASH-COMP solution will be evaluated using the usability test method.

KPI N°3: System Usability Scale (SUS) average

SUS [9] has become an industry standard (Figure 23), with references in over 1300 articles and publications. The noted benefits of using SUS include that:

- It is a very **easy scale** to administer to participants,
- It can be used on **small sample sizes** with reliable results,
- It is **valid** – it can effectively differentiate between usable and unusable systems.

The participant's scores for each question are converted to a new number, added together and then multiplied by 2.5 to convert the original scores of 0-40 to 0-100. Though the scores are 0-100, these are not percentages and should be considered only in terms of their percentile ranking.

Goals: to have **quantitative data** on the **usability** of the FLASH-COMP solution, from future users.

KPI Evaluation: Based on research, a SUS score evaluates the usability of the system as follows (Figure 24):

- 0 – 30: The worst imaginable,
- 30 – 50: Poor,
- 50 – 70: OK,
- 70 – 80: Good,
- 80 – 100: Excellent.



System Usability Scale

© Digital Equipment Corporation, 1986.

	Strongly disagree								Strongly agree
1. I think that I would like to use this system frequently	☐	☐	☐	☐	☐				
	1	2	3	4	5				
2. I found the system unnecessarily complex	☐	☐	☐	☐	☐				
	1	2	3	4	5				
3. I thought the system was easy to use	☐	☐	☐	☐	☐				
	1	2	3	4	5				
4. I think that I would need the support of a technical person to be able to use this system	☐	☐	☐	☐	☐				
	1	2	3	4	5				
5. I found the various functions in this system were well integrated	☐	☐	☐	☐	☐				
	1	2	3	4	5				
6. I thought there was too much inconsistency in this system	☐	☐	☐	☐	☐				
	1	2	3	4	5				
7. I would imagine that most people would learn to use this system very quickly	☐	☐	☐	☐	☐				
	1	2	3	4	5				
8. I found the system very cumbersome to use	☐	☐	☐	☐	☐				
	1	2	3	4	5				
9. I felt very confident using the system	☐	☐	☐	☐	☐				
	1	2	3	4	5				
10. I needed to learn a lot of things before I could get going with this system	☐	☐	☐	☐	☐				
	1	2	3	4	5				

Figure 23: System Usability Scale [9]

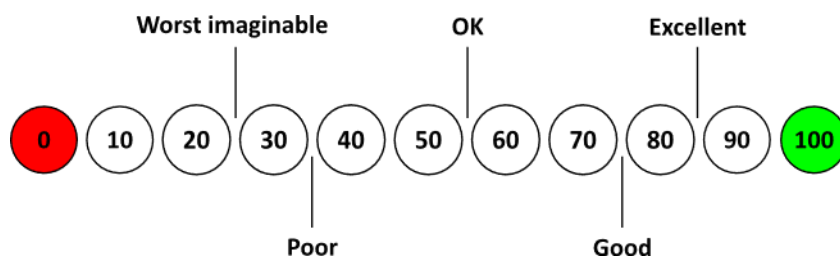


Figure 24: Evaluation of SUS score



KPI N°4: Survey / Users point of view

A survey, in native language, will be given to operators to complete tests with **qualitative data** and determine the participant's point of view with the FLASH-COMP solution.

Questions could be asked on:

- Satisfaction,
- Usability,
- Implementation needs,
- Etc.

Goals: to have qualitative data on the users' point of view of the FLASH-COMP solution design.

KPI Evaluation: The data collected at the SUS & usability test should match the qualitative data collected by the survey.

3.3.3 Training Evaluation

KPI N°5: Survey / Users point of view

A survey, in native language, will be given to operators **during training** to collect **qualitative data** and determine the participant's point of view with the FLASH-COMP solution.

Questions could be asked on:

- Learning agility,
- Learning difficulties,
- Learning needs,
- Skills development needs,
- Satisfaction,
- Etc.

Goals: to have qualitative data on the users' point of view of the FLASH-COMP solution training.

KPI Evaluation: The data collected will allow us to **restructure the training needs**.

3.4 Validation Protocols for industrial use cases' experiments

Based on the assessment methods, tools and KPIs presented in the previous sections, specific validation protocols for the testbeds' experiments to be organized and carried out in WP6 will be outlined in collaboration with the two companies and the other WP6 partners, in order to ensure coordinated activities, a smooth data collection and effective evaluation.

As reported in Figure 25, a structured approach will be followed to plan and document each experiment in collaboration with WP6 , i.e. 1) identification of the objective of the experiment and development of the specific validation protocol, 2) baseline measurement: measure the current state of the KPIs without the implementation of FLASH-COMP solutions. This will serve as a benchmark for comparison; 3) implementation: Implement the selected FLASH-COMP solutions in the use case; 4) measurement post-implementation: collect data and measure the KPIs after the implementation of digital technologies; 5) data analysis: compare the pre- and post-implementation measurements to assess the impact of FLASH-COMP.



Experiment ID and short title	Process Phase	Objective	KPI	Protocols and procedures	KPI "AS IS" value	KPI Target "TO BE" value	KPI Measured value	Comments

Figure 25 Experiment template

Moreover, the quantitative analysis will be complemented by a more qualitative analysis. In this respect, a structured collection of opinions and feedback from industrial users will be carried out and the gathered information will be documented using a SWOT analysis template to derive lessons learnt during the industrial pilots and recommendations for the future (Figure 26).

Strengths	Weaknesses
Lessons Learnt & Recommendations	
Opportunities	Threats

Figure 26 SWOT analysis template

4 Conclusions

The present deliverable 7.1 outlined the overall framework for the FLASH-COMP sustainability assessment. It further detailed the methods and tools that will be used in WP7 in order to assess the multi-dimensional impacts of the FLASH-COMP solutions when implemented in the two industrial use cases at Azimut and IAI. Digital innovation, economic, social, and environmental aspects are included to ensure adequate coverage of the different facets of Zero-Defect Manufacturing. Quantitative and qualitative data will be collected and analysed in collaboration with WP6 in the next steps of the FLASH-COMP project to guarantee a smooth sustainability assessment and derivation of recommendations and lessons learnt that can be helpful not only for the FLASH-COMP partners but also for other project stakeholders interested in the implementation of Zero-Defect Manufacturing.



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