Technologies for Manufacturing as a Service Ecosystems

Deliverable 5.1

Pilot validation plan and assessment report

WP5: Pilot operation and validation

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Executive Summary

Deliverable D5.1 sets the foundation for validating the T4M approach through a structured and methodical piloting process. This document outlines the strategy, methodology, and initial plans for validating the platform across three distinct industrial environments, referred to as Value Networks (VN1, VN2, and VN3). Each of these pilots represents a unique industrial context, from electronic board manufacturing to plastic injection moulding and complex engineering systems.

The validation process is an iterative effort which begins with the initial validation iteration, where early prototypes and core functionalities are tested in real-world settings. This phase is designed to gather early feedback, identify usability issues, and ensure that the foundational components of the T4M platform are working as intended. The insights gained here will inform further development and integration efforts.

Following this, the project will enter a transition phase, during which additional features and components will be integrated and tested incrementally. This phase ensures that the system evolves in a controlled manner, maintaining stability while expanding its capabilities. The final stage, the final validation iteration, will test the fully integrated T4M solution in operational environments, verifying that it meets all functional, technical, and business requirements to support this process, D5.1 introduces a comprehensive validation methodology that defines the validation plans for each Value Network and validation iteration. These plans detail how the piloting phase will be organized and executed under Tasks 5.2, 5.3, and 5.4. The methodology includes setting clear objectives, identifying relevant Key Performance Indicators (KPIs), preparing the validation environment, and ensuring ethical and legal compliance. It also emphasizes the active involvement of end users—not just as testers, but as contributors whose feedback shapes the evolution of the solution. Additionally, it defines detailed validation test cases, incorporates a proactive risk management strategy to ensure smooth execution and reliable results, and provides a structured validation schedule to guide pilot activities central to this methodology is the T4M assessment framework, which provides a consistent and transparent basis for evaluating the solution's performance. It combines both impact KPIs, which measure business-level outcomes such as efficiency gains and cost reductions and quality KPIs, which assess functional correctness, usability, and system performance Each Value Network has a tailored validation plan for the first iteration. VN1 focuses on optimizing the supply chain for electronic boards; VN2 explores the dynamic configuration of manufacturing services in the plastic and machining sectors; and VN3 validates semantic information modelling in engineering workflows. These pilots are supported by well-defined validation test cases and a robust assessment framework that combines both impact KPIs (e.g., production efficiency, cost reduction) and quality KPIs (e.g., functional correctness, usability, performance).

Finally, the document outlines a detailed issue management strategy to ensure that any problems encountered during validation are systematically tracked, analysed, and resolved. This structured approach supports continuous improvement and builds confidence in the reliability and robustness of the T4M solution.

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Acronyms and Abbreviations

Acronym	Description
AAS	Asset Administration Shell
AM	Additive Manufacturing
AMS	Additive Manufacturing Service
BC	Business Case
BFO	Basic Formal Ontology
BSC	Balanced Scorecard
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CNC	Computer Numerical Control
DC	Data space Connector
DoA	Description of Action
DT	Digital Twin
ERP	Enterprise Resource Planning
FA^{3}ST	Fraunhofer Advanced Asset Administration Shell Tools for Digital Twins
IDSA	International Data Space Association
IM	Information Model
IMF	Information Modelling Framework
IP	Identity Provider
KPI	Key Performance Indicator
MaaS	Manufacturing as a Service
MachS	Machining Service
MES	Manufacturing Execution System
PIMS	Plastic Injection Moulding Service
RFQ	Request for Quotation
SC	Supply Chain
T4M	Tec4MaaSEs
UC	Use Case
UFD	Utility Flow Diagram
UI	User Interface
UML	Unified Modelling Language
US	User Story
VN	Value Network
VP	Vocabulary Provider
WP	Work Package

1 Introduction

1.1 Purpose and Scope

The validation process implemented in the framework of Work Package 5 (Operation and Validation) is designed to systematically ensure that the T4M solution and its technologies can demonstrably meet user needs and intended use under real operational conditions. Rather than merely verifying compliance with technical specifications, it focuses on confirming that the delivered solution meets its intended purpose. The validation process can be broken down in several key steps:

1. **Prepare for validation**: The first step in the validation process is to develop a comprehensive **validation plan** that serves as the foundation for all validation activities. This plan should clearly define the overall approach, testing methods, success criteria, and the roles and responsibilities of each team member involved. By creating a well-structured plan, the team ensures that the validation process is aligned with the project's goals and accurately reflects user needs and system requirements. This preparation helps avoid misunderstandings, ensures consistency in testing, and sets clear expectations for how success will be measured throughout the validation cycle.
2. **Perform validation, record and analyse results, and manage Issues:** This step involves carrying out the planned validation activities in a controlled, yet realistic environment that closely mirrors actual operating conditions. All validation tests should be executed as defined in the validation plan, following the test cases, methods, and procedures established earlier. Throughout the process, every action is carefully documented—including the methods used, data collected, test results, and any problems encountered. The aim is to build a complete and traceable record of the validation effort. Once validation testing is complete, the collected evidence is reviewed and analysed. The actual outcomes are compared against the predefined success criteria to determine whether the system meets its intended requirements. At this stage, key performance indicators (KPIs) are also calculated to assess system effectiveness and impact. If deviations from expected results are found, their causes must be investigated through root cause analysis. Based on the findings, corrective actions are planned and implemented as needed. All identified issues must be logged in a structured manner—clearly describing the problem, its impact, and the steps taken to address it. If significant changes or fixes are introduced, retesting may be required to confirm that the system now behaves correctly and that no new problems have been introduced.
3. **Share guidelines and lessons learned for future adoption:** In the final phase, the focus shifts to capturing and sharing **guidelines and lessons learned** from the validation process. This involves documenting best practices, challenges encountered, and key insights gained, with the goal of supporting future implementations. These materials should be organized into practical, easy-to-follow guidance that can help new industrial stakeholders understand how to adopt and adapt the validated system or approach.

Task 5.1 (Pilot validation plan) covers two key phases of the validation process: *Preparation for Validation* (Step 1) and *Sharing Guidelines and Lessons Learned for Future Adoption* (Step 3). Task 5.2 (VN1 Pilot Operation and Validation), Task 5.3 (VN2 Pilot Operation and Validation), and Task 5.4 (VN3 Pilot Operation and Validation) focus on the *Perform validation, record and analyse results, and manage Issues* step.

Deliverable D5.1 (Pilot Validation Plan and Assessment Report) outlines the validation preparation activities conducted under Task 5.1. It presents the validation strategy, the validation preparation methodology and

the validation plans for the initial validation process, which will be carried out in the following tasks: Task 5.2, Task 5.3 and Task 5.4. It includes early activities from Task 5.2, Task 5.3 and Task 5.4. to describe the validation plans for the first iteration.

The final outcomes including the guidelines and lessons learned for future adoption: will be documented in Deliverable D5.4 (Impact Assessment and Lessons Learned), which will be submitted at the end of the project.

1.2 Relation with other deliverables

Figure 1 shows the relationship of Task 5.1 with the rest of T4M's tasks.

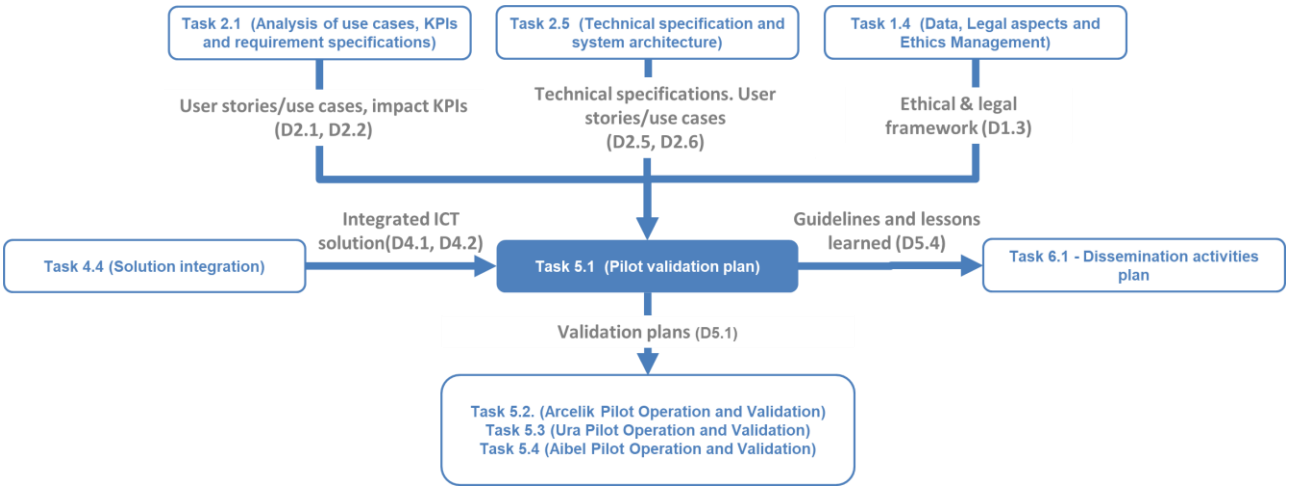

Figure 1: T5.1 relationship with other tasks and deliverables.

The main inputs for Task 5.1 are:

1. The results of Task 2.1 (Analysis of use cases, KPIs and requirement specifications) reported in D2.1 (Reference cases and actionable models for reconfigurable value networks and service decomposition v1). D2.1 provides an **initial description of the user stories and use cases** associated with each value network, along with the definition of **impact KPIs** for each value network and for the individual organizations involved in those networks. The final deliverable for Task 2.1 (D2.2: Reference cases and actionable models for reconfigurable value networks and service decomposition v2) is planned for release by December 2025.
2. The results of Task 2.5 (Technical specification and system architecture) reported in D2.5 (Tech4MaaSEs architecture blueprint and specifications v1). D2.5 includes details on the **technical specifications** along with revised and extended **user stories**. The final deliverable for Task 2.5 (D2.6 Tech4MaaSEs architecture blueprint and specifications v2) is planned for release in December 2025.
3. The results of Task 4.4 (Solution Integration) are presented in Deliverable D4.1 (Tech4MaaSEs Integrated Platform v1). D4.1 provides the initial version of the **integrated ICT solution**, which combines the available services developed in WP2 (Reference Framework, Specifications, and Core Enablers), WP3 (DT Modelling, Operation, and Governance for Resilient Value Networks), and WP4 (Integration and Pilot Deployments) for validation. The final deliverable for Task 4.4, D4.2 (Tech4MaaSEs Integrated Platform v2), is scheduled for release in 2026.
4. The legal and ethical framework included in deliverable D1.3 (Data Management Plan v1).

The main outputs of Task 5.1 include the **validation strategy**, the **validation preparation methodology, and the validation plan** for the initial iterations of the validation process, as documented in Deliverable D5.1. This plan for the **first validation iteration** will be implemented in the following validation tasks (i.e., Task 5.2, Task 5.3 and Task 5.4) and the initial results will be reported in D5.2 (Pilots Execution and Evaluation v1). The validation plan for the **final iteration** will be included in deliverable D5.3 (Pilots Execution and Evaluation v2) along with the results. The final outcomes of Task 5.1 comprising **guidelines and lessons learned to support future adoption**—will be captured in Deliverable D5.4 (Impact Assessment and Lessons Learned), which will be submitted at the end of the project and feed dissemination activities in Task 6.1 (Dissemination Plans).

1.3 Structure of the document

The document is organized into the following main sections:

- **Section 2 – T4M Validation Strategy:** This section introduces the overall validation strategy adopted in the project. It outlines the guiding principles and best practices, describes the phased validation approach, and provides an overview of the three Value Network pilots (VN1, VN2, VN3). It also introduces the TAM-based assessment framework, defines the impact and quality KPIs, and presents the techniques and tools used for validation, including the issue management strategy.
- **Section 3 – T4M Validation Preparation Methodology:** This section details the methodology used to prepare for validation. It includes the definition of validation objectives and scope, the selection of KPIs, the setup of the validation environment, and the procedures for participant involvement and ethical compliance. It also covers the development of the validation protocol, risk management planning, and the scheduling of validation activities.
- **Section 4 – Validation Plan: First Validation Iteration:** This section presents the detailed validation plans for the initial iteration of each Value Network pilot. For each VN (VN1, VN2, VN3), it includes the purpose and scope, selected KPIs, validation environment setup, test protocols, risk management strategies, and a timeline of activities. Each plan is tailored to the specific context and objectives of the respective pilot.
- **Conclusions:** This section summarizes the key elements of the validation plan and outlines the next steps in the validation and assessment process.
- **Appendixes:** The annexes provide supporting templates and tools used during the validation process, including:
    - **Appendix A:** Brief & Informed Consent Template – used to ensure ethical compliance and participant awareness.
    - **Appendix B:** Generic Usability Questionnaire Template – adapted from the System Usability Scale (SUS) to collect structured user feedback**.**
    - **Appendix C:** Common validation test cases that are shared among the pilots tp ensure consistency in assessment and comparability of results.

2 T4M validation strategy

This section outlines the T4M validation strategy and its supporting elements. It begins by presenting the best practices that guide the overall validation process, followed by a detailed description of the T4M validation approach, including its phased implementation through pilot deployments. The section also provides an overview of the value network pilots involved, identifies key validation stakeholders, and introduces the TAM assessment framework with defined impact and quality KPIs. Additionally, it describes the validation techniques applied throughout the process and explains the issue management strategy used to track, resolve, and learn from identified issues.

2.1 Best practises

Defining a sound Validation Strategy relies on best practices drawn from key international standards, such as ISO/IEC/IEEE 12207 (Systems and software engineering — Software life cycle processes)[1] and ISO/IEC/IEE 29119 (Software and systems engineering — Software testing)[2] that offer complementary guidance. ISO/IEC/IEEE 12207 emphasizes that validation must be systematic, planned early in the life cycle, and integrated into the broader project framework, with activities scaled according to risk severity. Meanwhile, IEEE 29119 contributes a structured approach to experimentation and testing, promoting comprehensive documentation and systematic use of various testing levels and types to ensure robust validation outcomes.

Building upon these standards, best practices can be summarized as follows:

- **Early integration and planning:** Validation must not be an afterthought; it must be incorporated into project plans from the start.
- **Iterative and continuous validation**: Validation should occur throughout the life cycle, not only at the final stages.
- **Risk-based prioritization**: Focus effort according to the impact of failure.
- **Independence of validation team from development team**: Separate validation teams help ensure impartial evaluation.
- **Clear, formal documentation**: Plans, designs, cases, results, and deviations must be documented clearly.
- **Use of diverse validation techniques**: Combine different techniques during the validation process.
- **Evidence-based assessment**: Validation success must be based on measurable evidence, not assumptions.
- **Traceability to Requirements**: Every validation activity should be traceable back to specific user needs or operational requirements.
- **Problem Management and Revalidation**: Deviations must be systematically tracked, corrected, and retested.

2.2 T4M validation approach

The validation process aims to ensure that a system, product, or solution meets its intended use and stakeholder expectations in a real or simulated operational environment. It confirms that "**we built the right system**"—that is, the outcome aligns with user needs, requirements, and business objectives.

[1] ISO/IEC/IEEE 12207:2017 - Systems and software engineering — Software life cycle processes
[2] ISO/IEC/IEEE 29119-1:2022 - Software and systems engineering — Software testing — Part 1: General concepts

T4M's validation approach relies on the deployment and operation of **three value network pilots**, which serve as a crucial part of the process. Unlike laboratory or simulated tests, pilot deployments introduce the system into real or near-real operational environments while limiting exposure to a small group of users (i.e., participants) on a controlled operational context. The primary objective is to observe actual user interactions, identify unforeseen issues, and ensure the system performs correctly and reliably under practical working conditions. Each pilot focuses on specific **user stories incorporating various T4M components** to ensure comprehensive coverage.

T4M's validation strategy follows an **incremental and iterative approach**, ensuring a structured and controlled rollout of new features while enabling continuous refinement based on feedback from industrial users. This approach accelerates value creation by enabling technical partners to deliver core functionalities early in the process, allowing for the gradual introduction of additional features. By doing so, risks are minimized, and stability and performance improvements are achieved before advancing further.

A key element of this strategy is the continuous engagement of end users throughout the design - development-validation cycle. Their ongoing involvement ensures that the solution is aligned with actual operational needs, making it more relevant, user-centric, and enhancing overall satisfaction.

Initial Validation Iteration: Validation of prototypes and core functionalities

The initial validation iteration, spanning from June 2025 to November 2025, serves as the foundation for verifying the early-stage viability of the T4M solution. It involves a first version of the system, which includes a prioritized subset of core features most critical to the project's strategic goals and stakeholder expectations.

This early release is not intended to reflect the complete functionality of the final solution. Rather, it provides a focused, tangible starting point for validation activities. The aim is to test how well the initial implementation supports essential use cases per value network pilot and whether it meets the basic requirements of usability, functionality, and technical performance. These early validations help identify any misalignments or shortcomings before more complex components are introduced.

Validation during this phase is performed using a combination of structured and exploratory techniques, such as scenario-based testing to assess how the system performs under representative workflows, functional testing to ensure that the implemented features behave as intended, usability testing to evaluate the interface and user interaction patterns, or demonstration workshops with stakeholders, where prototypes are reviewed in guided sessions for immediate feedback.

This hands-on involvement of end users ensures that feedback is collected early, analysed and reported (D5.2). The insights gathered are then used to guide refinements, fix bugs, improve the user interface, and enhance feature design in subsequent development cycles.

Transition Phase: Integration and incremental testing

Following the completion of the initial prototype validation, the project enters a transition phase, spanning from December 2025 to May 2026, focuses on the progressive integration of new functionalities and incremental system validation. This phase is critical for managing complexity as the solution evolves toward its final form.

As updated components and new features become available through ongoing development efforts they are systematically integrated. This integration is done in a controlled manner, ensuring backward compatibility, interface coherence, and minimal disruption to existing functionality.

Each integration cycle is immediately followed by a tailored set of validation activities. These activities replicate the core steps used in the initial iteration but are adapted to reflect the increased functional scope and interdependencies by including new test cases when required and engaging stakeholders regularly through periodic feedback sessions.

Final validation iteration: Final solution validation

The final validation iteration focuses on testing the complete T4M solution in real-world conditions. At this stage, spanning from June 2026 to October 2026, the system should be fully developed, stable, and ready to deliver its expected value in the pilot environments. The core objective of this phase is to confirm that the solution meets all functional and non-functional requirements as defined by end users, technical partners, and strategic stakeholders. This involves not only ensuring technical correctness but also validating that the system behaves reliably and efficiently in real-world scenarios.

The final validation serves as the definitive test of whether the solution is **fit for purpose**. It must demonstrate that it supports critical workflows effectively, adheres to agreed- standards, and is usable and acceptable to its target users. In particular, the solution must align with the **Key Performance Indicators (KPIs)** established earlier in the project and support the **business objectives** of the involved value networks. Results are reported in D5.3.

The validation process across all iterations is guided by a comprehensive **validation plan** that acts as a structured roadmap for executing all related activities. This plan ensures that the solution remains aligned with user needs and business objectives throughout development. It also provides clear guidance for documenting each validation step, collecting objective performance data, and conducting thorough analyses to support evidence-based decision-making.

2.3 Value network pilots overview

This section offers just a brief introduction, outlining the composition and scope of each value network involved in the validation phase for contextual reference. Details are available in Deliverable D2.1.

2.3.1 Value Network 1 (VN1) overview

Value Network (VN1) centres on manufacturing and distributing electronic boards (EBs) for leading consumers engaged in the production of white goods. In essence, this overarching process involves mutual interactions among distinct sets of stakeholders. These include (a) Consumers 1 and 2, represented by two factories from the Arcelik Group (ARCELIK) namely the Arctic Romania Washing Machine Factory (AR) and Arcelik Bolu Cooking Appliances Factory (AB), respectively, who place orders for electronic boards, and (b) major Producers 1 and 2, namely ACRON (ACRON) and Karel Electronics (KAREL), respectively, responsible for designing, developing, and supplying EBs to the consumers for the production of their final products.

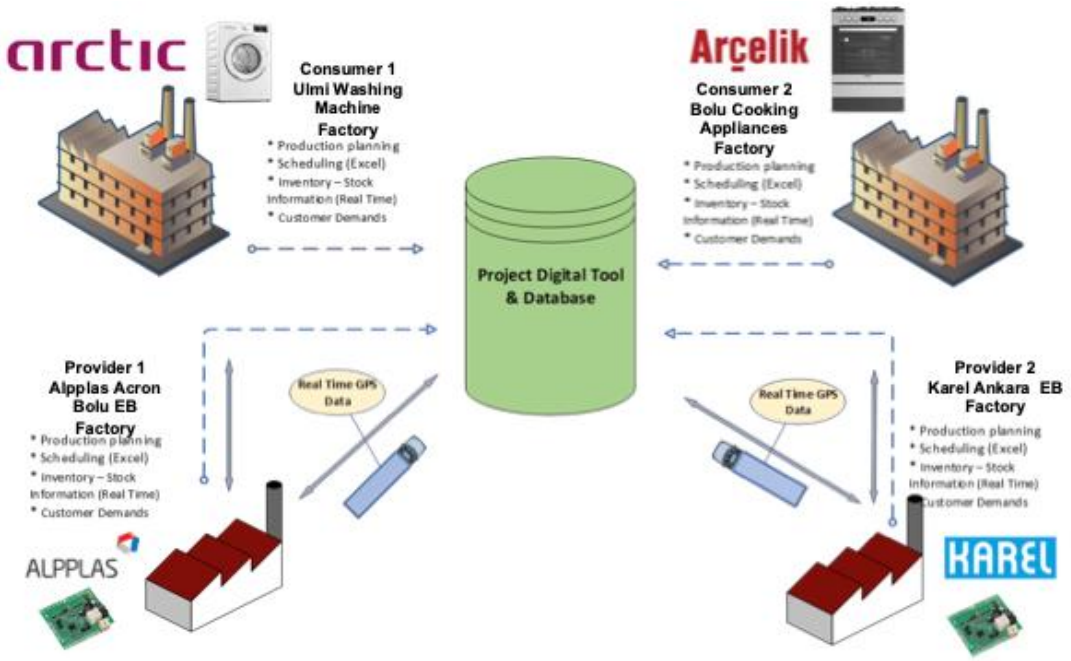

Figure 2: VN1 ecosystem (from D2.1- under refinement for the final version)

VN1 involves:

- **Arcelik (ARCELIK):** Arcelik Group involves two different factories:
  - **Arctic Romania Washing Machine Factory (AR):** Part of the Arcelik Group, which offers products in 147 countries with 30 production facilities in 9 countries (Turkey, Romania, Russia, China, South Africa, Thailand, India, Pakistan and Bangladesh) and 12 brands. The Romania facility serves as Consumer 1, specializing in washing machine production and requiring a steady supply of electronic control boards for their appliances.
  - **Arcelik Bolu Cooking Appliances Factory (AB):** Another key facility of the Arcelik Group located in Bolu, Turkey, serving as Consumer 2. This factory focuses on the production of cooking appliances including ovens, cooktops, and range hoods, requiring electronic boards for their products.
- **ACRON (ACRON):** Acron or can be referred as Alpplas, serving as Producer 1 and playing a central role in the value network. ACRON currently manages the allocation of electronic board production between its own factory and other providers for the Arcelik group consumers.
- **Karel Electronics (KAREL):** One of the top 15 manufacturers of telephone exchanges in the world, with more than 10 million consumers worldwide across 30 countries. In VN1, KAREL serves as Producer 2, providing electronic board manufacturing capabilities to complement AC's capacity.

Building and configuring supply chains for electronic board procurement by traditional means (e.g., web searches, telephone, email, etc.) is effort intensive and may lead to errors. T4M aims to deploy technologies as core enablers of more efficient supply chain management. The vision of VN1 is to illustrate how a T4M-based platform leverages advanced analytics and optimization services to transform the electronic board supply chain, enabling better demand forecasting, optimized production planning, and improved inventory management. The T4M platform should provide a common ground to optimize the entire supply chain from order placement to delivery through data-driven decision making. This involves several main processes

focused on: (1) Provider/Consumer registration and onboarding, (2) Electronic board procurement and order management.

Providers'/Consumers' onboarding process

The T4M platform should allow both electronic board providers and consumers to register and complete their onboarding process, establishing the foundation for efficient supply chain operations.

The registration process begins when a company's Planning Department (PD) representative accesses the T4M platform to register their organization as either a Provider or Consumer. Through a guided wizard, they provide essential company information including profile details, capabilities, and other relevant organizational data. Providers also declare their production capacity, while consumers specify their quality standards and requirements. All parties must accept confidentiality agreements to ensure secure information exchange. Following registration, the IT representative grants T4M secure access to relevant manufacturing-related information and systems. Usage conditions and data governance policies are defined during this step to ensure secure and compliant data exchange between all parties in the value network.

T4M then validates the onboarding process by verifying that all required information has been correctly provided and is accessible. Once validation is complete, providers become eligible to receive electronic board orders, and consumers can begin placing orders through the platform.

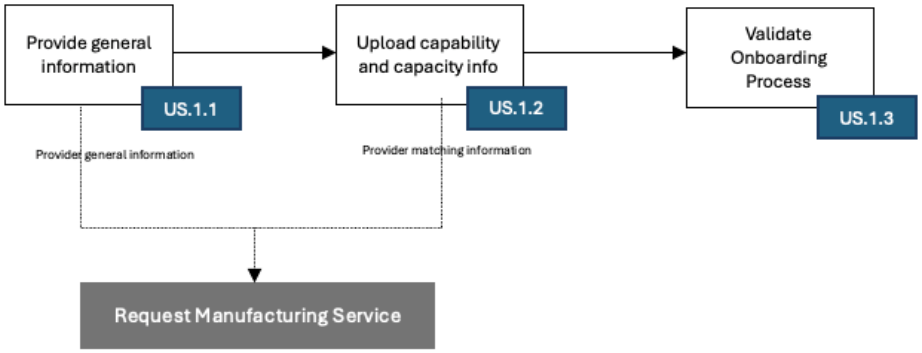

Figure 3: VN1 Providers' onboarding process and information flows and related User Stories (From D2.1)

Request Manufacturing Service

The T4M platform should support the complete lifecycle of electronic board procurement, from demand analysis through order fulfilment and performance evaluation. The procurement process begins with consumers' Planning Departments accessing the T4M platform to create manufacturing service requests for electronic boards. They specify the required electronic board variants (from approximately 130 available types), quantities, production plans, and quality requirements.

T4M's analytics components then process this request along with historical data to extract manufacturing service requirements and identify optimal provider configurations. The system leverages predictive analytics to forecast demand patterns and optimization services to evaluate different supply scenarios, considering factors such as provider capabilities, capacity availability, location, costs, and pre-agreed Quality of Service (QoS) criteria.

Based on this analysis, T4M presents ranked provider configurations to the consumer, who can then request quotations from selected providers. A negotiation phase follows where consumers and providers align on pricing, quantities, delivery terms, and other conditions. Throughout this process, T4M facilitates information exchange and tracks all interactions. Once agreements are reached, consumers release manufacturing service orders through the platform. T4M enables both parties to monitor order progress and track production status, providing visibility into the manufacturing process and enabling proactive management of potential deviations such as demand fluctuations or machine breakdowns. Upon order completion, T4M facilitates performance evaluation where both consumers and providers assess the service delivery based on agreed KPIs. This feedback helps improve future procurement decisions and strengthens the relationships between consumers and providers in the value network.

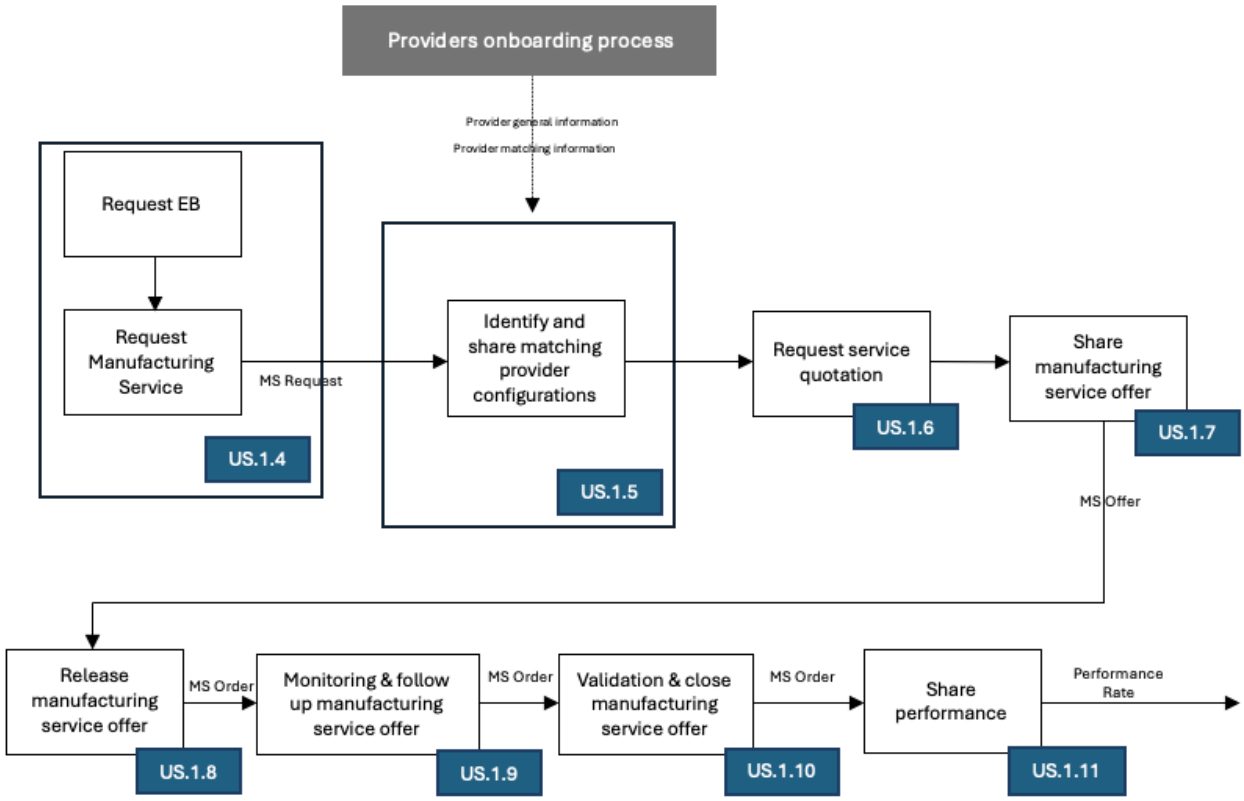

Figure 4: VN1 Request manufacturing service and information flows

2.3.2 Value Network 2 (VN2) overview

Value Network 2 (VN2) involves a manufacturing ecosystem in the plastic injection moulding domain, composed of three companies that represent different roles in relation to a MaaS approach (i.e., MaaS Consumer and MaaS Provider of manufacturing services), thus illustrating highly distinct and representative business cases.

Furthermore, VN2 is realised by three different types of manufacturing services; that are *Additive Manufacturing Services (including or not finishing processes), Machining Services; Plastic Injection Services* It also includes a set of manufacturing resources which can be used in different sectors. Further details on the involved manufacturing services are included in Annex A.

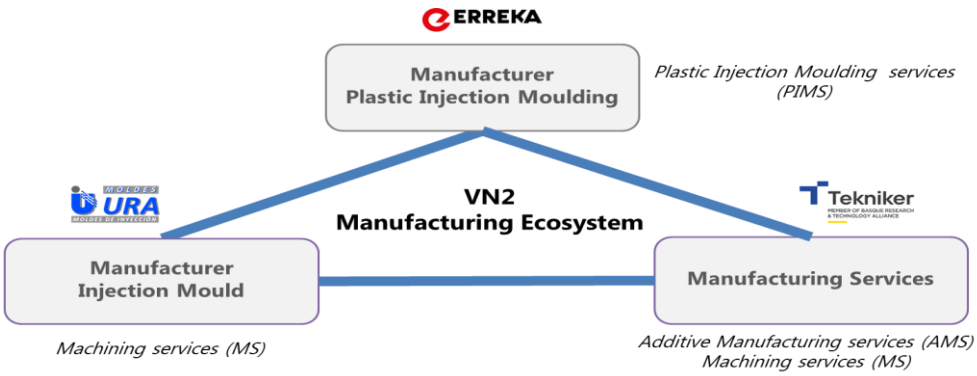

Figure 5: VN2 ecosystem (from D2.1)

VN2 involves:

- **ERREKA Plastics (ERREKA)** is part of ERREKA Group. ERREKA is dedicated to designing and manufacturing plastic injection components for a wide range of industries. ERREKA is a world- class manufacturer of precision injection moulded thermoplastic components for the automotive industry and participates, actively, in various automotive clusters. ERREKA's headquarters are in Spain, and it involves production sites in Czech Republic and Mexico which include a wide variety of plastic injection moulding machines that can provide Plastic Injection Moulding Services (PIMS). ERREKA plays the role of MaaS Provider of Plastic Injection Moulding Services and MaaS Consumer of Additive Manufacturing and Machining Services depending on the context.
- **Moldes Ura (URA)** is an SME specialized in the design, feasibility assessment, and manufacturing of moulds for different sectors. Its expertise spans across plastic injection, rubber, die casting, sheet moulding as well as compound and resin transfer moulding. URA integrates a strong design department with expertise in CAD/CAM, as well as machining capabilities and a manufacturing shopfloor that can provide Machining Services (MachS). Available machining resources involve CNC Milling machines, CNC machining centres and CNC turning machines among others. URA plays the role of MaaS Provider of Machining Services and MaaS Consumer of Additive Manufacturing and Machining Services depending on the context.
- **TEKNIKER** is a research centre specialised in Manufacturing and has in place a manufacturing shopfloor which supports its research activities, as well as the provision of industrial services. TEKNIKER's manufacturing shopfloor involves several manufacturing resources that can provide both Additive Manufacturing Services (AMS) and Machining Services (MachS). Available resources involve Additive Robotic Cell, CNC Milling machines, CNC machining centres and CNC Grinding machines among others. TEKNIKER play the role of MaaS Provider of Additive Manufacturing and Machining Services and MaaS Consumer of Machining Services depending on the context.

Building and reconfiguring supply chains matching consumers and providers of manufacturing services by traditional means (e.g., web searches, telephone, email, etc.) is effort intensive and may lead to errors. T4M aims to deploy technologies as core enablers of MaaS practices. In turn, the vision of VN2 is to illustrate how a MaaS Marketplace based on T4M technologies leverages the flexible (re)configuration of value chains in the injection moulding domain, due to disruptive events such as, for example, the use of new technologies through servitisation (to avoid incurring high investment costs) or demand peaks, and enables a more intensive usage of underused production capacity (thereby increasing circularity) by offering it as a service to third parties (i.e., on a sharing basis). The MaaS Marketplace should provide a common ground to bring

together on MaaS basis, both consumers and providers of distributed manufacturing services, enable ad-hoc configuration of matching value chains, and follow up the manufacturing service order from release till completion. This involves two main processes: (1) Providers' onboarding process and (2), On demand procurement process.

Providers' onboarding process

The T4M Marketplace should allow providers to register and further describe the manufacturing services by registering and broadcasting the capabilities and capacities of shared manufacturing resources.

The onboarding process for manufacturing service providers in the T4M Marketplace should follow a structured approach. It begins with provider registration, where the provider's sales representative logs into the Marketplace and accesses the "Provider's Area" to submit company details via a guided wizard. This includes selecting supported manufacturing services from a predefined list and specifying shipping destinations. To ensure confidentiality during service delivery, the provider also signs a non-disclosure agreement (NDA). Then, the provider's IT representative grants data access to T4M by sharing essential information about the manufacturing resources—such as capabilities, capacities, technical specifications, and production planning data—through a secure user interface. Usage conditions for this data are defined during this step, and providers can update the information at any time. Finally, T4M validates the onboarding process by verifying that all required information has been correctly provided and is accessible as per the onboarding guidelines. Once validation is complete, the provider becomes eligible to receive manufacturing service requests through the platform.

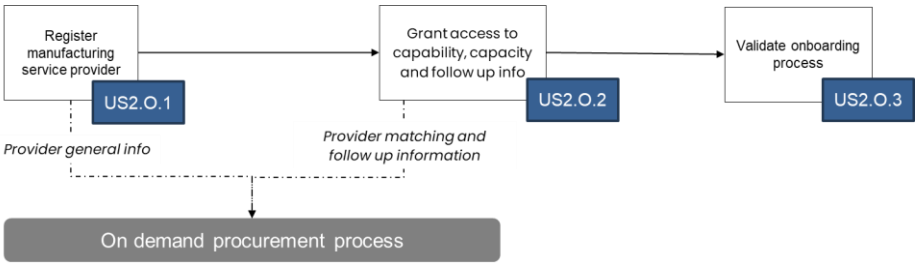

Figure 6: VN2 Providers' onboarding process and information flows and related User Stories (From D2.1)

On demand procurement process

The T4M Marketplace should support the procurement process of manufacturing services, including ad hoc configuration of matching value chains, negotiation flows, manufacturing servicer order release and follow up, and collection of performance ratings**.**

The on-demand procurement process begins with the customer requesting a manufacturing service, providing specifications, quantities, deadlines, and any relevant technical details. In response, the platform shares matching supply chain configurations, identifying suitable providers and possible collaboration models based on resources' capabilities and capacities (i.e., time availability. Next, the customer can request service quotations from selected providers. At this stage, a negotiation phase may take place, where the customer and providers engage in discussions to align on pricing, lead times, terms, and service conditions. This negotiation ensures that both parties reach a mutually beneficial agreement before moving forward. Following successful negotiation, providers share their final manufacturing service offers, reflecting agreed terms. The customer then releases a manufacturing service order (Phase 5) to the chosen provider, officially

confirming the engagement. The provider begins execution, and the customer can follow up on the service order, tracking production status and any updates through the platform. Once the service is delivered, the customer validates the manufacturing service order, confirming that all requirements have been met. Finally, the provider shares performance data, including delivery metrics and quality indicators, feeding into a feedback loop

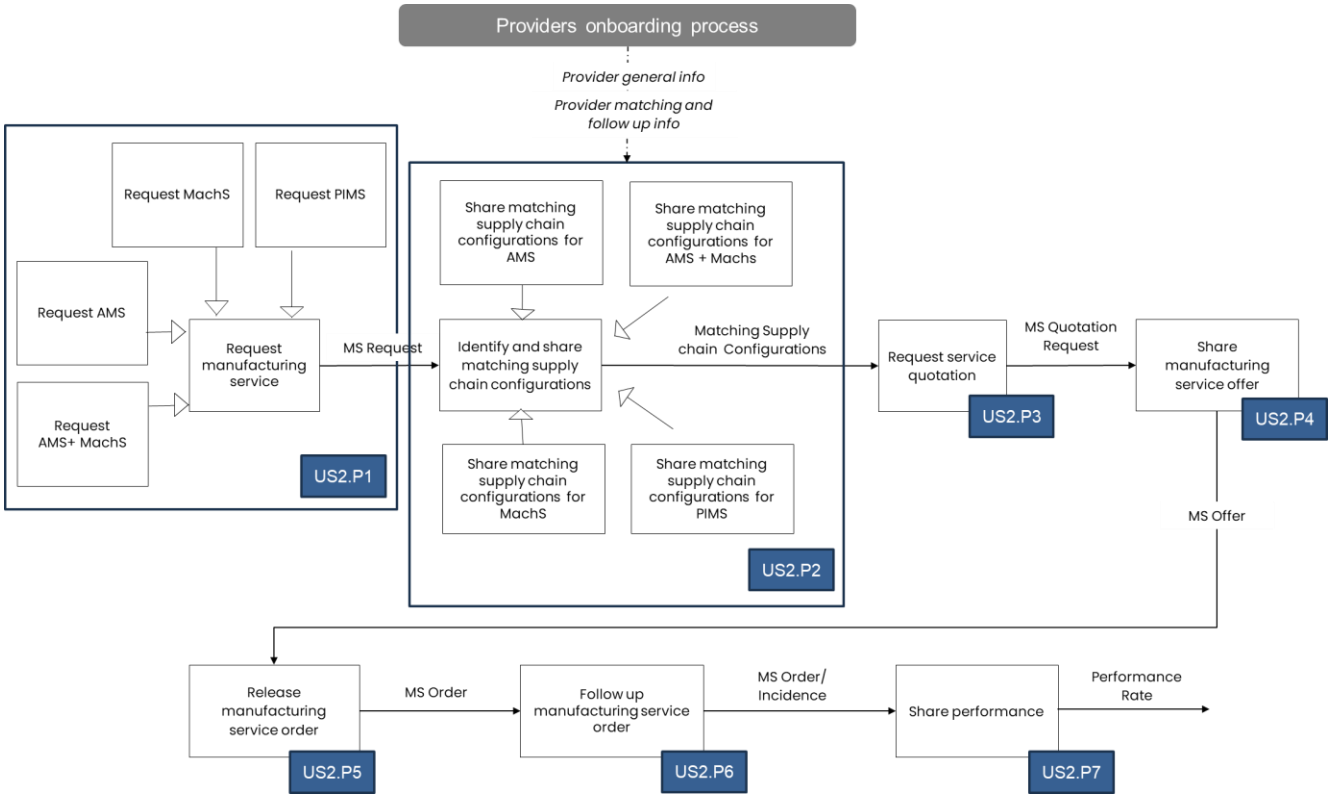

Figure 7: VN2 On demand procurement process and information flows

2.3.3 Value Network 3 (VN3) overview

Value Network 3 (VN3) focuses on the construction of facilities for the hydrogen market, involving a complex ecosystem of stakeholders and highly specialized equipment. At the core of VN3 is the EPC (Engineering, Procurement, and Construction) contractor, AIBEL, which acts as the consumer of manufacturing services. AIBEL collaborates with a network of equipment suppliers (providers) to deliver large-scale hydrogen production facilities. These projects are capital-intensive, often exceeding billions of euros, and require precise coordination across multiple phases of design, procurement, and delivery.

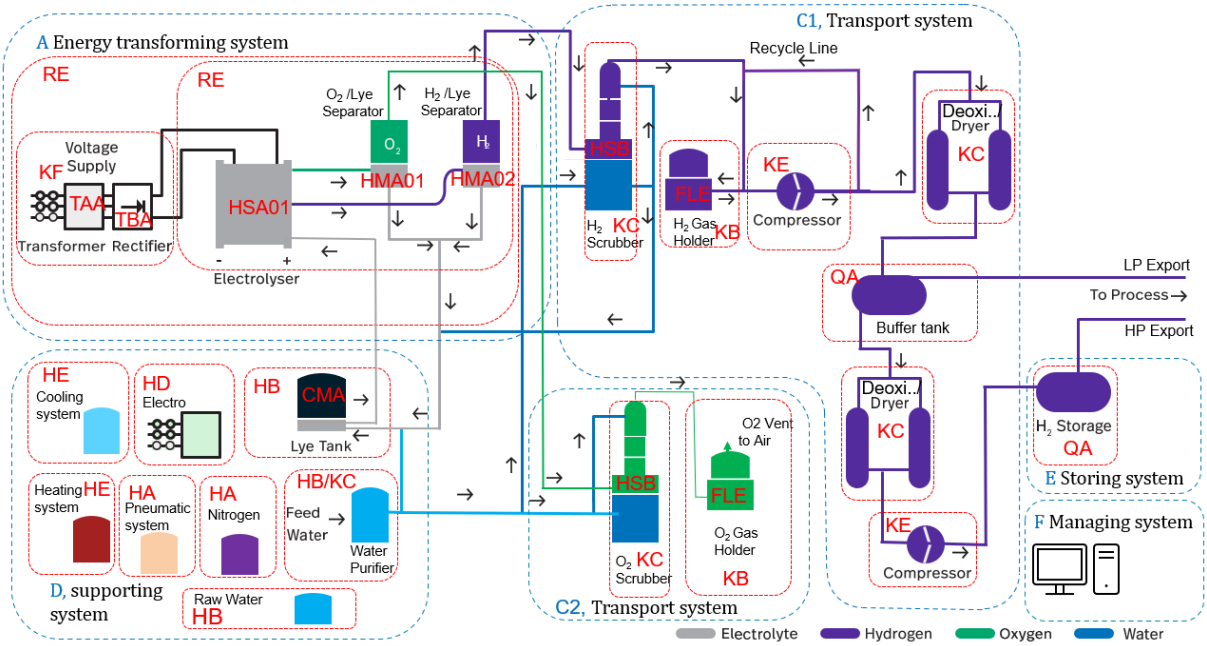

Figure 8: VN3 ecosystem (From D2.1)

VN3 involves:

- **AIBEL:** A Norwegian EPC company with extensive experience in the oil & gas and offshore wind sectors, now expanding into the hydrogen sector. AIBEL is responsible for the overall design, procurement, and integration of the facility components. In VN3, AIBEL acts as the MaaS Consumer, orchestrating the procurement and integration of equipment from various suppliers.
- **Endress+Hauser:** One of AIBEL's equipment suppliers (Providers) among several in a network of pre-qualified suppliers responsible for delivering highly customized or engineered equipment. Each supplier is selected through a competitive tendering process and collaborates closely with AIBEL throughout the project lifecycle.

The development of hydrogen facilities involves iterative, information-heavy interactions between AIBEL and its suppliers. These interactions are mainly managed through static documents (e.g., PDFs, spreadsheets), which are prone to errors, delays, and inefficiencies. VN3 aims to transform this process by introducing a model-based approach using AAS (Asset Administration Shell), IMF (Information Modelling Framework) and the T4M platform. The vision of VN3 is to demonstrate how a T4M-enabled MaaS ecosystem can streamline the procurement and delivery of complex, customized or engineered equipment. By replacing traditional document exchanges with structured, machine-readable Information, VN3 seeks to reduce lead times, improve traceability, and enhance collaboration between stakeholders. VN3 is structured around a series of phases that mirror the lifecycle of a facility development project:

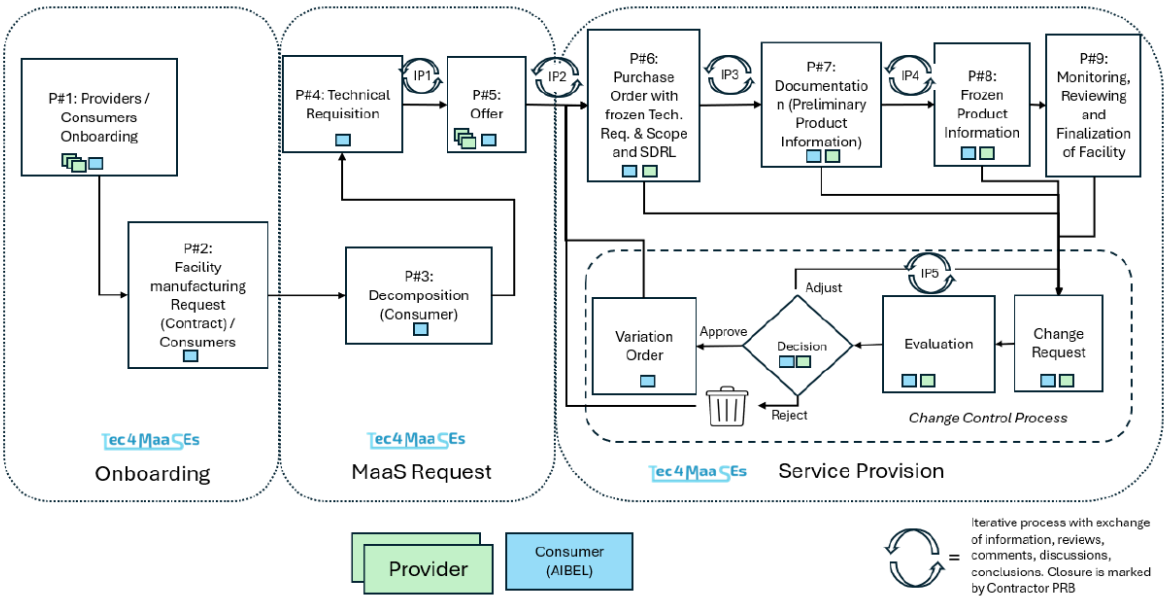

Figure 9: VN3 Facility development through T4M (From D2.1)

Onboarding process

AIBEL (Consumer) and its suppliers (Providers) register on the T4M platform. Roles such as Package Responsible Buyer (PRB) and Package Responsible Engineer (PRE) are defined for both parties.

Facility decomposition and technical requisition

AIBEL decomposes the facility by using the IMF language and creates an AAS for each equipment, which constitutes the first version of the Consumer Information Model (CIM) detailing technical requirements. These AASs are shared with selected suppliers through the T4M platform.

Tendering and offer submission

Suppliers respond with AAS, which include preliminary Provider Information Model (PIM) detailing product specifications. An iterative process allows for clarifications, updates of IMF model, and collaborative refinement of the AAS (CIMs and PIMs).

Purchase order and provider information

Once a supplier is selected, Aibel issues a purchase order. The supplier updates the PIM with documentation and frozen product information for Aibel's review and acceptance.

Change control and iterative collaboration

Throughout the project, changes may arise. A structured change control process allows for the evaluation and approval of variation orders, which are reflected in updated AAS (CIMs and PIMs) and IMF model.

Project completion and validation

The equipment and facility are delivered and validated. The T4M platform supports final PIM acceptance, performance evaluation, and closure of the manufacturing service order.

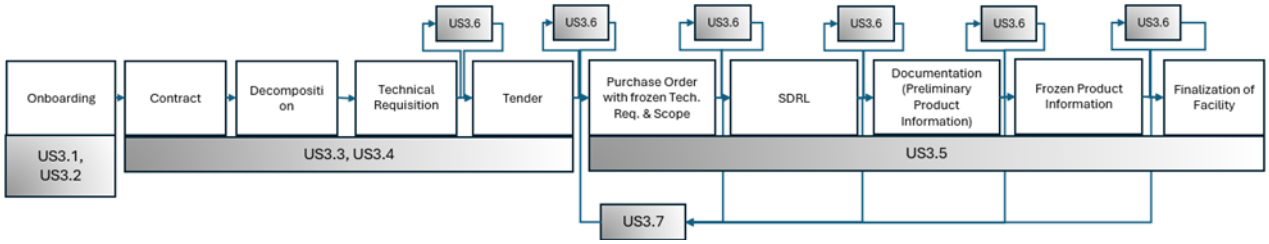

Figure 10: VN3 User Stories (From D2.1).

T4M should ensure secure, interoperable, and traceable information exchange across the value network:

- Structured onboarding of stakeholders.
- Data space governance and certification.
- ID management.
- Creation and management of AAS (CIMs and PIMs).
- Purchase order process (Request, quotation and order) including negotiations.
- Iterative collaboration through annotations and comments to CIMs/PIMs content.
- Change control and variation order management.
- Performance tracking and validation.

2.3.4 Value network pilots' coverage

This section outlines the architectural readiness of each component, indicating which are included in the initial validation iteration and which are planned for the final iteration and provides a consolidated view of how the Tec4MaaSEs (T4M) components are distributed and validated across the three Value Network pilots (VN1, VN2, and VN3).

2.3.4.1 T4M components

The section introduces the core components of the T4M platform that are being validated through the Value Network pilots. It presents an overview of each component composition, ownership, and readiness status, distinguishing between those available for the initial validation iteration and those scheduled for later phases. The section also includes a mapping of components to specific Value Networks, ensuring traceability between technical capabilities and pilot objectives.

Figure 11 shows the most recent version ofT4M's architecture at the time this deliverable was issued.

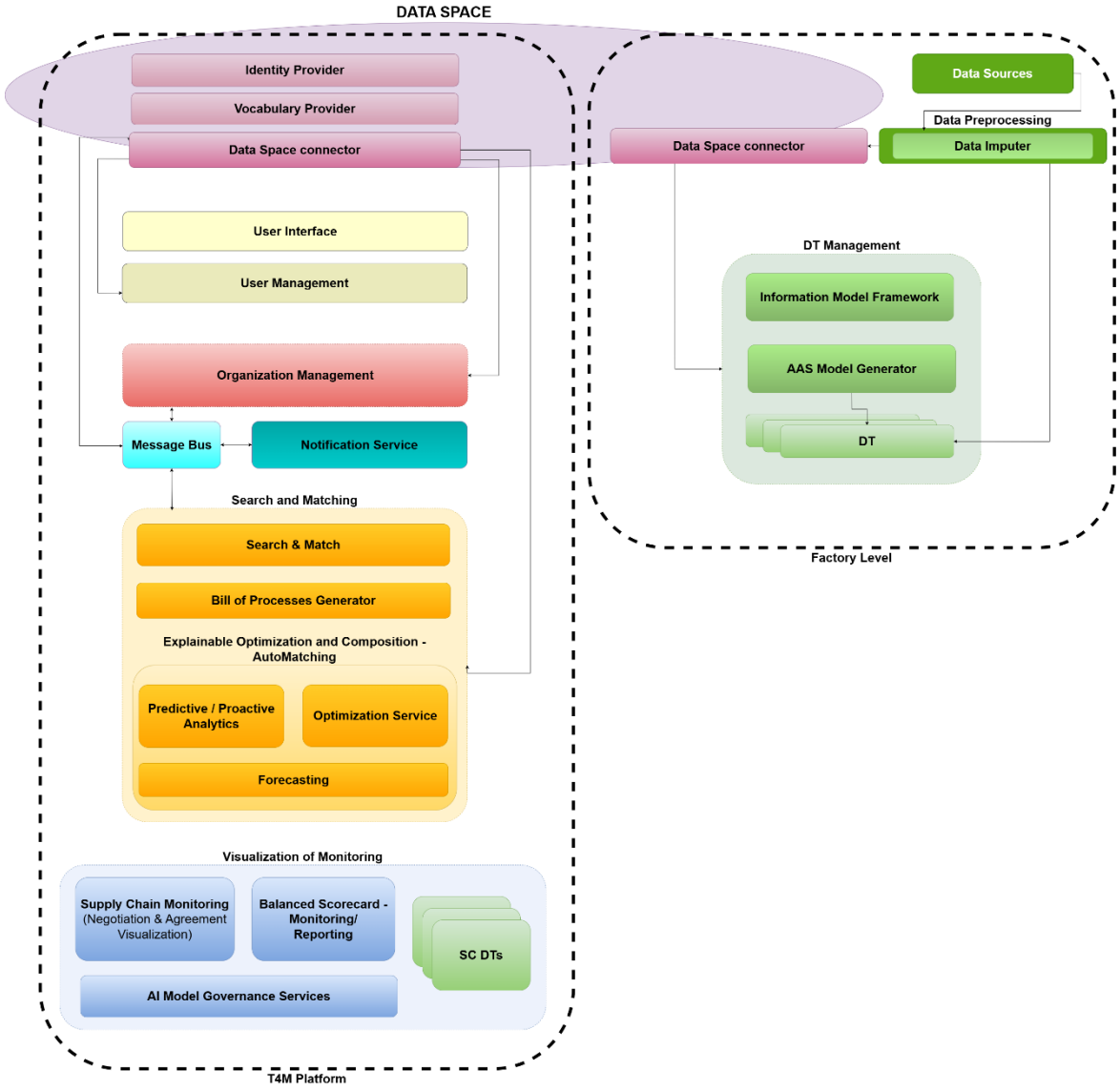

Figure 11: T4M architecture – Updated from D2.5.

Table 1 outlines the architectural components that are either **fully or partially developed within the framework of the T4M project** as described in D2.5. The components with initial working or proof of concept prototypes ready for the first validation iteration are highlighted in green while those to part of the final validation iteration are highlighted in yellow.

Table 1: T4M components readiness

Code	T4M component	Composition		Owner	Readiness	
		GUI	Backend service		Initial Validation iteration	Final Validation iteration
IMF	Information Model Framework	•	•	UiO	Initial version	Final version
AMG	AAS Model Generator	•	•	IOSB	Initial version Integrated)	Final version Integrated)
DI	Data Imputer	-	•	ATC	-	Final version integrated

Code	T4M component	Composition		Owner	Readiness	
		GUI	Backend service		Initial Validation iteration	Final Validation iteration
DT	Digital Twins			IOSB	Initial version integrated	Final version
DSC	Dataspace Connector	•	•	TEKNIKER	Initial version integrated	Final version integrated
IP	Identity Provider	•	•	TEKNIKER	-	Final version integrated
VP	Vocabulary Provider	•	•	TEKNIKER	-	Final version integrated
UM	User Management	•	•	ATC	Initial version integrated	Final version integrated
OM	Organization Management	•	•	ATC	Initial version integrated	Final version integrated
SM	Search & Match	•	•	ATC	Initial version integrated	Final version integrated
BoPG	Bill of Processes Generator		•	TEKNIKER	Initial version integrated	Final version integrated
OS	Optimization Service		•	AUEB	Initial version not integrated	Final version integrated
AS	Predictive / Proactive Analytics	•	•	UoM/ SmartOpt (Forecasting)	Initial version not integrated	Final version integrated
SCM	Supply Chain Monitoring (Negotiation and Agreement Visualization)	•	•	MAG	Initial version not integrated	Final version integrated
BS	Balanced Scorecard – Monitoring/ Reporting	•	•	MAG	Initial version not integrated	Final version integrated
AIM	AI Model Governance Services	•	•	MAG	Initial version not integrated	Final version integrated
NS	Notification Service	•	•	ATC	Initial version integrated	Final version integrated

Value Network Pilots incorporate only the essential components necessary to fulfil the user stories documented as results of Task 2.1 (Analysis of the use cases, KPIs and requirements specification).Table 2 summarizes these components and indicates whether their initial versions are validated in the first iteration as part of the first validation iteration (highlighted in green) or will be included in the subsequent iterations as part of the final validation iteration (highlighted in yellow). Further details on each value network pilot are provided in section 0.

Please note that this information reflects the status based on the available information in D2.1 (Reference cases and actionable models for reconfigurable value networks and service decomposition v1) and D2.5

(Tech4MaaSEs architecture blueprint and specifications v1) and may evolve throughout the project's development.

Table 2: Summary table. T4M components involved in the target VN pilots

Code	T4M component	VN1	VN2	VN3
IMF	Information Model Framework	-	-	●
AMD	AAS Model Generator	●	●	--
DI	Data Imputer	●	●	-
DT	Digital Twins	●	●	●
DSC	Dataspace Connector	●	●	●
IP	Identity Provider	●	●	●
VP	Vocabulary Provider	●	●	●
UM	User Management	●	●	●
OM	Organization Management	●	●	●
SM	Search & Match	●	●	●
BoPG	Bill of Processes Generator	-	●	-
OS	Optimization Service	●	●	-
AS	Predictive / Proactive Analytics	●	●	-
SCM	Supply Chain Monitoring (Negotiation and Agreement Visualization)	●	●	●
BS	Balanced Scorecard – Monitoring/ Reporting	●	●	●
AIM	AI Model Governance Services	●	●	●
NS	Notification Service	●	●	●

2.4 Validation stakeholders

This section outlines the key stakeholders who are involved in or impacted by the validation activities, specifying who should be engaged and the role each plays in the validation process. In the context of a validation process, stakeholders include individuals, groups, or organizations that are directly involved in, contribute to, or are affected by the validation of a system, solution, or process.

Table 3 outlines the key stakeholders participating in T4M's validation process, detailing the specific role and responsibilities each stakeholder holds within the validation activities.

Table 3: T4M v validation stakeholder

Stakeholder	Organization / Role	Involvement in Validation
Project Coordinator	Project partner responsible for the overall project management (MAG).	Oversees the entire project, ensuring alignment with objectives, timeline, and budget. Oversee overall risk landscape, consolidate reports, and coordinate response for critical or systemic risks.
Operation and Validation Leader	Project partner responsible for WP5 devoted to Operation and Validation activities (TEKNIKER) .	Manages and coordinates all activities related to validation (Work Package 5

Stakeholder	Organization / Role	Involvement in Validation
		Coordinate with VN Pilot teams and technical partners to ensure effective implementation of the validation phase. Communicates potential validation risks to project coordinator
Component Owners	Technical partner responsible of a specific component. See Table 1: T4M components .	Develop and deploy system components, support integration and technical troubleshooting. Participate in the assessment of the validation results, when relevant.
Value Network Pilot Technical Partners	Local technical partner supporting each value n network Pilot (i.e., SMO for VN1, TEKNIKER for VN2, MAG for VN3)	Act as local technical hub between the pilot site coordinators and the component owners. Avoid miscommunication between technical teams and pilot sites. Participate in the assessment of the validation results, when relevant.
Value Network Pilot Coordinators	A coordinator for each Value Network Pilot involved in T4M (i.e. ARCELIK, for VN1, URA for VN2 and AIBEL for VN3)	Coordinate validation tasks and value network level and deliverables. Interact with Pilot Site Coordinators and Value Network Pilot Technical Partner. Manage and communicate potential risks to the Operation and Validation Leader-
Pilot Site Coordinators	A coordinator for each of the partners involved in the VN Pilots (i.e. ARCELIK, ACRON, KAREL, URA, ERREKA, TEKNIKER, AIBEL)	Manage local implementation of value network pilots; coordinate participants and interact with its supporting Value Network Pilot technical partner. . Responsible for the assessment of the validation results.
Pilot Site IT Representative	A person in charge of IT activities at Pilot site level. One representative per Pilot Site (i.e. ARCELIK, ACRON, KAREL, URA, ERREKA, TEKNIKER, AIBEL).	Support technical activities such as deployment and configuration of components at Pilot Sie. Interact with Pilot Site Coordinators and Value Network Pilot Technical Partner.
Pilot Site Data Protection Officers	A data protection office for each of the partners involved in the VN Pilots (i.e. ARCELIK, ACRON, KAREL, URA, ERREKA, TEKNIKER, AIBEL)	Ensure user data is handled in compliance with GDPR and other relevant regulations.
Value Network Pilot Participants	End users from each partner participating in the Value Network Pilots (i.e., ARCELIK, ACRON, KAREL, URA, ERREKA, TEKNIKER, AIBEL) actively involved to the validation activities.	Interact with the system in operational settings; provide feedback and report issues. Execute validation tests, provide feedback and report bugs.

2.5 T4M assessment framework

This section presents the T4M assessment framework, which offers a structured approach to systematically evaluating the quality and impact of the T4M solution under real-world conditions. It serves as the foundation of the validation methodology, ensuring that the assessment is conducted in a consistent, objective, and transparent manner.

The framework defines what will be measured, how it will be measured, and against which criteria the results will be interpreted. It integrates both qualitative and quantitative methods, combining user feedback, system metrics, and business indicators to provide a comprehensive view of how well the solution performs. T4M assessment framework involves two main categories KPIs: (1) Impact KPIs and (2) Quality KPIs,

Impact KPIs

In the context of a validation plan, Impact KPIs serve as critical indicators for evaluating the broader value and effectiveness of the solution being tested., Impact KPIs assess the real-world outcomes and long-term benefits that the solution delivers to the organization or ecosystem. These indicators are designed to measure how the implementation of T4M contributes to strategic- business level goals. They provide tangible evidence of how the validated solution performs under realistic conditions and whether it creates measurable value when applied in the pilot environment.

Impact KPIs for each value network and associated partner were identified and detailed in Deliverable D2.1 along with clear measurement criteria, data sources, and target values. All the selected Impact KPIs involve quantitative metrics. Impact KPIs will be **measured during the final validation iteration**, with baseline values established during the setup phase of that iteration.

VN1 Impact KPIs

This section outlines the Impact KPIs related to VN1, as detailed in D2.1. Table 4 offers a summarized overview of all selected Impact KPIs.

Table 4: VN1 Impact KPI summary (From D2.1))

Impact KPI	VN1 Pilot Site	Baseline (As-Is)	Success criteria -Expected impact (To Be)
Production Capacity Utilization Rate	ACRON	88%	+4% (to 92%)
	KAREL	77%	+13% (to 90%)
Order Fulfilment Rate (Perfect OTIF)	ACRON	91%	+5% (to 96%)
	KAREL	92%	+3% (to 95%)
Electronic Board Stock Keeping	Arcelik Bolu (AB)	15 days	-53% (to 7 days)
	Arctic Romania (AR)	15 days	-53% (to 7 days)

Table 5: Production Capacity Utilization Rate KPI (From D2.1)

KPI	**Production Capacity Utilization Rate**
Definition	The ratio of actual production capacity usage divided by design capacity. This KPI measures how effectively the electronic board manufacturing facilities are utilizing their available production capacity.

Measurement method	ACRON: Data extracted from Production Planning module of SAP system, available as Excel file (.xls) KAREL: Data extracted from Production Planning module of Oracle ERP and Excel macros, available as Excel file (.xls)
Calculation method	Production Capacity Utilization Rate = (Actual Monthly Production Output / Design Capacity) × 100. Where: - Actual Monthly Production Output: Confirmed production quantity recorded in the system - Design Capacity: Maximum production capacity registered in the Production Planning module
Baseline	ACRON: 88%. KAREL: 77%
Success criteria	ACRON: Increase to 92% by the end of the project KAREL: Increase to 90% by the end of the project

Table 6: Order Fulfilment Rate KPI (Perfect OTIF) (From D2.1)

KPI	**Order Fulfilment Rate (Perfect OTIF)**
Definition	This KPI measures the percentage of customer orders delivered on time and in full (OTIF). It reflects the ability to efficiently fulfil customer orders by meeting delivery deadlines and providing all the correct electronic board items.
Measurement method	ACRON: Data extracted from SAP system (logistics module) KAREL: Data extracted from Oracle ERP system
Calculation method	Order Fulfilment Rate = (Number of Orders Delivered on Time and In Full / Total Number of Customer Orders) × 100. Measurement period: Monthly basis
Baseline	ACRON: 91%. KAREL: 92%
Success criteria	ACRON: Increase to 96% by the end of the project KAREL: Increase to 95% by the end of the project

Table 7: Electronic Board Stock Keeping KPI (From D2.1)

KPI	**Electronic Board Stock Keeping**
Definition	This KPI measures approximately how many days of electronic board inventory the facility maintains to support production. It reflects the efficiency of inventory management and the impact of improved demand forecasting.
Measurement method	Arcelik Bolu: Data extracted from SAP ERP system Arcelik Romania: Data extracted from SAP ERP system
Calculation method	Stock Days = (Current EB Stock / Average Daily EB Consumption). Where: Current EB Stock: Current inventory of electronic boards- Average Daily EB Consumption: Monthly consumption / 30 days
Baseline	Arcelik Bolu: 15 days. Arcelik Romania: 15 days
Success criteria	Arcelik Bolu: Reduce to 7 days by the end of the project. Arcelik Romania: Reduce to 7 days by the end of the project

VN2 Impact KPIs

This section outlines the Impact KPIs related to VN2, as detailed in D2.1. Table 8 offers a summarized overview of all selected Impact KPIs.

Table 8: VN2 Impact KPI summary (From D2.1)

Impact KPI	VN2 Pilot Site	Baseline (As-Is)	Success criteria -Expected Impact (To Be)
Machine Capacity Utilization Rate	URA	*	+15%
	ERREKA	*	+10%
	TEKNIKER	*	+15%
Reduction in investment costs (Ownership vs service)	URA	N/A	Reduction of investment costs by 15% during the validation period
Investment cost in stored part	ERREKA	*	Reduction of inventory costs of spare parts by 25%
Product lead time	URA	*	-25%
	ERREKA	*	-25%
	TEKNIKER	*	-25%

Note: ***** The baseline value will be calculated at the beginning of the final iteration of the validation phase

Table 9**,** Table 10**,** Table 11**,** Table 12 provide details on the impact KPIs selected in the framework of VN2 along with the measurement and calculation methods, baseline and expected results.

Table 9 Machine Capacity Utilization Rate KPI (From D2.1)

KPI	**Machine Capacity Utilization Rate**
Definition	Machine Capacity Utilization Rate measures the extent to which a company's machinery is being utilized compared to its full potential during a given period. It is especially crucial in manufacturing environments where machinery plays a significant role in operations. By highlighting periods when machines are underutilized, this KPI helps identify inefficiencies that can be addressed to improve productivity. The KPI is expressed as a percentage, showing the proportion of the machines' available time that is spent in operation.
Measurement method	URA: Data related to Actual Machine Hours Used is extracted from the follow up of work orders stored in the Manufacturing Execution Database. and accessible through excel files. ERREKA: Data is extracted from the machine and the follow up of work orders, stored in the Manufacturing Execution System, and accessible through excel files. TEKNIKER: Data is extracted from the machine and stored in the internal monitoring system, and accessible through an API and user interface.
Calculation Method	The KPI is calculated by dividing the total number of hours the machines of a specific section where in operation over a specific period. (Actual Machine Hours Used) in a by the total number of hours the machine of the specific section was available for use during the same period (Total Available Machine Hours) and multiplying it by 100. $$Machine\ Capacity\ Utilization\ Rate = \frac{Actual\ Machine\ Hours\ Used\ \ (in\ period)}{Total\ Available\ Machine\ Hours\ (in\ period)}\ x\ 100$$

	Where: Actual Machine Hours Used: It represents the aggregate number of hours that the machines in a specific section were in operation over a defined period. Total Available Machine Hours: It represents the aggregate number of hours that machines within a particular section were accessible for utilization within the identical timeframe.
Baseline	To be calculated at the beginning of the final iteration of the validation phase
Success criteria	URA: Increase of 15% from baseline. ERREKA: Increase of 10% from baseline. TEKNIKER: Increase of 15% from baseline.

Table 10 Reduction in investment costs (Ownership vs service (From D2.1)

KPI	**Reduction in investment costs (Ownership vs service**
Definition	This KPI measures the percentage reduction in investment costs when a business transitions from owning manufacturing assets to utilizing a service-based model. It evaluates the cost savings achieved by comparing the total cost of ownership (TCO) of assets with the costs associated to on demand access to manufacturing services provided by third parties. This helps organizations understand the financial benefits of adopting service-based solutions over maintaining and owning their own infrastructure or equipment. In the framework of T4M this KPI will refer to the use of additive manufacturing services instead on investing in the introduction of new Additive Manufacturing infrastructure over a specific period
Measurement method	*TCOOwnership*: represents the aggregated values of Initial Purchase Costs, Installation and Setup Costs, Operating Costs, Maintenance and Support Costs, Depreciation, Financing Costs, and End-of-Life Costs. *TCOService*: represents the aggregated costs of Additive Manufacturing services requested in each period. Data related to TCOOwnership will be estimated based on third part information on the ownership costs of an Additive Manufacturing Cell. Data related to TCOService will be accessible from T4M.
Calculation Method	The KPI is calculated by dividing the difference between the total cost of ownership of manufacturing machinery and the costs of additive manufacturing services orders placed over a specific period by the total cost of ownership of manufacturing machinery and multiplying the result it by 100. $$Reduction\ in\ investment\ costs = \frac{\text{TCOOwnership}\ (in\ period) - \text{TCOService}\ (in\ period)}{\text{TCOOwnership}\ (in\ period)}\ x\ 100$$ where: $$\text{TCOOwnership}\ (in\ period) = \frac{\text{TCOOwnership}}{service\ life}\ x\ \text{period}$$ $$\text{TCOService}\ (in\ period) = \sum \text{Cost of Additive Manufacturing services}\ (in\ period)$$
Baseline	Not applicable.
Success criteria	URA: Reduction of investment costs by 15% during the validation period

Table 11 Investment cost in stored part) (From D2.1)

KPI	**Investment costs in stored spare parts (Storage cost of spare parts)**
Definition	This KPI evaluates the effectiveness of on-demand manufacturing in reducing the cost of storing spare parts. On-demand manufacturing aims to produce goods as they are needed, reducing the need for large inventories and, consequently, lowering storage costs. In the framework of T4M the focus in on the spare parts for injection moulds.
Measurement method	Data related to spare parts is managed through ERREKA's ERP system.
Calculation Method	The KPI is calculated by multiplying the spare part cost by the minimum required spare part number. Now, due to the complexity and long lead-time, in many cases it is required to keep some quantity of spare parts in stock. $Reduction\ in\ investment\ costs = \text{Spare part cost}\ x\ Spare\ part\ number$ Related data are List of critical spare parts, Minimum required quantity, Individual cost
Baseline	To be calculated at the beginning of the final iteration of the validation phase
Success criteria	ERREKA: Reduction of inventory costs of spare parts by 25%.

Table 12 Product lead time (From D2.1)

KPI	**Product lead time**
Definition	When focusing on the procurement of manufacturing services, Product Lead Time specifically measures the duration taken from the moment an order is placed with a third-party service provider to the point when the outsourced service or component is received and ready for use or integration into the final product. Components of product lead time in the procurement of manufacturing services involve: (1) Order Placement Time (i.e., the time taken to finalize and place the order with the service provider); (2) Service Provider Lead Time (i.e., the duration the service provider needs to complete and deliver the service); (3) Transportation Time (I.e., the time taken for the service or component to be transported from the service provider to the receiving location), and (4) Inspection and Integration Time (i.e., the time required to inspect the received service/component and integrate it into the final product). In the framework of T4M the focus in on reducing the Product Lead Time by contributing to a shorter Order Placement Time as the rest of the concepts are not affected by the introduction out T4M.
Measurement method	Data related to Supplier Selection Time, Order Preparation Time and Order Transmission will be accessible from T4M. Baseline values are experience based.
Calculation Method	The Order Placement Time refers to the duration taken from the moment a decision is made to procure a service or component until the order is officially placed with the service provider. It is calculated by adding together the total number of days used to select Supplier, to prepare the order and to transmit it. $Order\ Placement\ Time = Time\ to\ Select\ Supplier + Time\ to\ Prepare\ Order + Order\ Transmission\ Time$ Where:

	Supplier Selection Time: It represents the number of days needed to choose the appropriate service provider, which may involve identifying suitable suppliers, evaluating quotes, negotiating terms, and selecting the best option. Order Preparation Time: It represents the number of days needed to prepare the purchase order, which includes specifying quantities, prices, delivery dates, and other relevant details. Order Transmission Time: It represents the number of days needed to send the approved purchase order to the service provider.
Baseline	To be calculated at the beginning of the final iteration of the validation phase
Success criteria	URA: Reduction of 25% from baseline. ERREKA: Reduction of 25% from baseline. TEKNIKER: Reduction of 25% from baseline.

VN3 Impact KPIs

This section outlines the Impact KPIs related to VN3, as detailed in D2.1.Table 13 offers a summarized overview of all selected Impact KPIs.

Table 13: VN3 Impact KPI summary (From D2.1)

Impact KPI	VN3 Pilot Site	Baseline (As-Is)	Success criteria -Expected impact
Duration from receival until documents and information are imported and made available in the relevant systems	AIBEL/ Endress+Hauser	*	To reduce the duration by 50% through the usage of standardized information packages and in-formation models with machine understandable data.
The timespan between the submission of information and its issuance to the supplier	AIBEL/ Endress+Hauser	*	To reduce the duration by 30% through the usage of standardized information packages and in-formation models with machine understandable data.
Number of automated import/export processes	AIBEL	*	> 5 processes
Verification effort of comments and changes	AIBEL	*	To reduce verification time by 30%

Note: ***** The baseline value will be calculated at the beginning of the final iteration of the validation phase

Table 14: Duration from receival until documents and information are imported and made available in the relevant systems (From D2.1)

KPI	**Duration from receival until documents and information are imported and made available in the relevant systems**
Definition	The duration from receival of an information package from the suppliers until documents and information are imported, or manually entered, and made available in the relevant systems.
Measurement method	Data is collected from AIBEL's engineering systems.
Calculation Method	At present mode of operation, drawings and documents are normally sent by e-mail. We will measure the time in two steps: • Time from e-mail is received by the Document Control Centre (DCC) until the drawings and documents are made available in the Document Control system. • Time from drawings and documents that are available in the Document Control system until the information and data are manually entered or imported into the relevant IT systems.
Baseline	To be calculated at the beginning of the final iteration of the validation phase.
Success criteria	To reduce the duration by 50% through the usage of standardized information packages and information models with machine understandable data.

Table 15: The timespan between the submission of information and its issuance to the supplier (From D2.1)

KPI	**The timespan between the submission of information and its issuance to the supplier**
Definition	The duration from when documents, drawings and information are ready until they are issued to the supplier.
Measurement method	Data is collected from AIBEL's engineering systems.
Calculation Method	This KPI will be measured (time) in two steps: • Time from when information is ready in calculations and data registers until it is documented in drawings and documents which can be delivered to the Document Control Centre (DCC). • Duration of time from drawings and documents that are delivered to DCC until they are available for the supplier.
Baseline	To be calculated at the beginning of the final iteration of the validation phase.
Success criteria	To reduce the duration by 30% through the usage of standardized information packages and information models with machine understandable data.

Table 16: Number of automated import/export processes (From D2.1)

KPI	**Number of automated import/export processes**
Definition	This KPI measures the number of import/export processes (mentioned in VN3-KPI-1 and VN3-KPI-2) that are automated. An import/export process is defined as a process to move information from an information exchange package (For instance AAS) into the

	relevant IT systems or export the information the opposite way. That the process is automated means in this case that it is executed automatically by a computer program.
Measurement method	Data is collected from AIBEL's engineering systems.
Calculation Method	Count number of processes which are automated.
Baseline	To be calculated at the beginning of the final iteration of the validation phase.
Success criteria	> 5 processes.

Table 17: Verification effort of comments and changes (From D2.1)

KPI	**Verification effort of comments and changes.**
Definition	Time (in manhours) used by the PRE and other engineers to verify comments and changes.
Measurement method	Data is collected from AIBEL's engineering systems.
Calculation Method	Time (manhours) used by the PRE and other engineers to verify comments and changes.
Baseline	To be calculated at the beginning of the final iteration of the validation phase.
Success criteria	To reduce verification time by 30%.

Quality KPIs

This section outlines the key quality metrics defined, so far, within the T4M assessment framework and provides general information on their measurement and calculation methods. Specific measurement details and acceptance criteria are documented within the corresponding validation test cases. Quality KPIs can be relevant to both initial and final validation iterations.

ISO/IEC 25010:2011 (Software product quality model, characteristics, and sub-characteristics) [3] defines a comprehensive set of quality characteristics and sub-characteristics for software systems. It serves as a structured reference for identifying key quality metrics (i.e., quality KPIs) during the software validation process. These KPIs are measurable indicators, which may include both quantitative and qualitative metrics, used to assess whether the system performs correctly from functional and technical perspectives and satisfies the expectations and needs of its end users.

[3] https://www.iso.org/obp/ui/#iso:std:iso-iec:25010:ed-1:v1:en

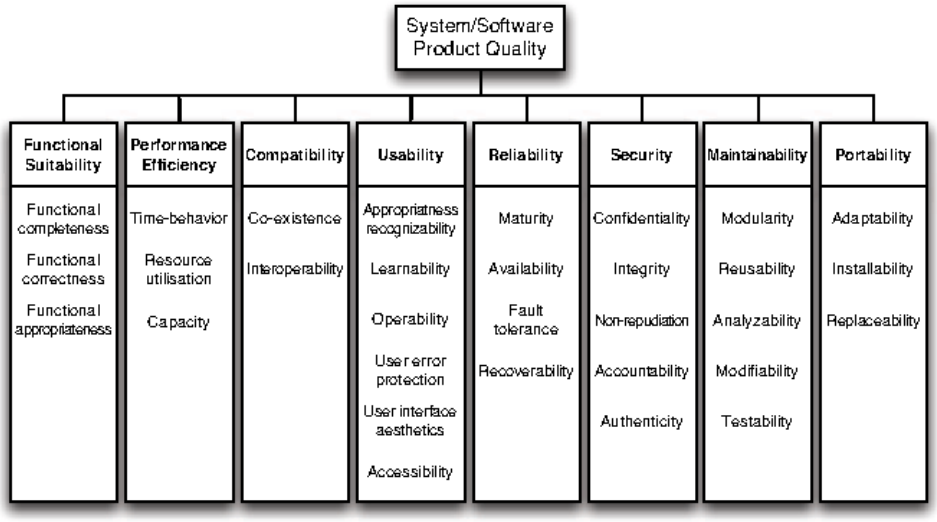

Figure 12: Quality characteristics - ISO/IEC 25010:2011

Functional Suitability

Functional suitability refers to how well a product or system can provide functions that meet the stated and implied needs. Functional Correctness refers to how well a product or system provides the correct results with the needed degree of precision.

Table 18: Quality KPI- Functional correctness rate

KPI	**Functional correctness rate (%)**
Definition	This KPI measures the proportion of functional test cases that produce the correct and expected output, verifying that the system behaves as expected. It aims to ensure that the software system functions as intended and delivers accurate results for all defined use cases and scenarios.
Measurement method	Measurement methods vary depending on the specific test cases and may involve either manual or automated data collection approaches.
Calculation Method	$Functional\ Correctness\ Rate\ (\%) = \frac{Number\ of\ Passed\ Functional\ Test\ Cases}{Total\ Functional\ Test\ Cases\ Executed} x\ 100$
Comments	Specific measurement and calculation methods and acceptance criteria are described in the validation plans defined for each validation iteration.

Table 19: Quality KPI- Number of Critical Defects

KPI	**Number of Critical Defects (unit)**
Definition	This KPI tracks the total number of defects classified as *critical* that are identified during the validation process. Critical defects are those that cause complete system failure, compromise safety, or result in non-compliance with key requirements.
Measurement method	Critical defects are identified and recorded following the issue management procedure in section 2.7.
Calculation Method	*Number of Critical Defects = Total count of defects classified as "critical" during the measurement period.*

Comments	The severity classification criteria and defect identification process are detailed in section 2.7.

Usability KPIs

Usability KPIs aim to evaluate how well a product or system can be used to achieve specified goals effectively, efficiently, and satisfactorily. These KPIs are applicable to components or features involving a graphical user interface.

Table 20: Quality KPI- Number of usability issues

KPI	**Number of usability issues**
Definition	It measures the total number of distinct problems encountered by users when interacting with the system during the validation phase. These issues may include confusing navigation, unclear instructions, layout inconsistencies, inaccessible features, or actions that lead to user errors or frustration. This KPI helps to assess the user-friendliness and design effectiveness of the solution.
Measurement method	Screen video recording during the execution of functional tests, alternatively in person observer.
Calculation Method	To analyse the video recording and annotate any potential usability problem
Comments	Specific measurement and calculation methods and acceptance criteria are described in the validation plans defined for each validation iteration.

Table 21: Quality KPI- Perceived usabiility

KPI	**Perceived usability**
Definition	It refers to the user's subjective assessment of how easy, efficient, and satisfying a system or solution is to use. It captures the personal experience and impressions of end users during or after interacting with a digital product.
Measurement method	Depending on the target components or functionality a unique measurement method or a combination of different measurement method can be involved: • Extended usability questionnaires, adapted from the System Usability Scale (SUS) 4, including open-ended comment sections after task completion. These questionnaires can be tailored to evaluate specific components or functionalities of the system. • User interviews conducted using a semi-structured format, guided by insights gathered from the open-ended comments provided in the usability questionnaires.
Calculation Method	To analyse the usability questionnaires and performs user interviews when relevant. Quantitative values are calculated following the questionnaire assessment guidelines
Comments	Specific measurement and calculation methods and acceptance criteria are described in the validation plans defined for each validation iteration.

[4] SUS_A_quick_and_dirty_usability_scale

Performance KPIs

Performance KPIs aim to evaluate the performance efficiency of a software product, specifically assessing how well it performs in terms of response time, resource usage, and capacity under defined conditions.

Table 22 Quality KPI- Response time

KPI	**Response time (seconds)**
Definition	It refers to the time taken by a system component (e.g., service, module, or interface) to respond to a request, regardless of whether the request originates from a GUI, API, or another system component. It aims to evaluate the performance, responsiveness, and reliability of system components
Measurement method	Depends on the target components or functionality different approached can be used such as implementing component -level Logs or using system monitoring tools-
Calculation Method	To analyses the collected information. $Response\ Time\ (seconds) = Timestamp\ of\ response - Timestamp\ of\ request$
Commnents	Specific measurement and calculation methods and acceptance criteria are described in the validation plans defined for each validation iteration.

2.6 Validation techniques

The purpose of this section is to identify a set of validation techniques to be used to ensure that T4M solution and components meet their intended purpose, perform correctly under specified conditions, and comply with functional and non-functional requirements. These techniques support the structured evaluation of system behaviour and serve as evidence for compliance, correctness, and quality assurance.

The following techniques can be used at different stages of the validation process, depending on the iteration, how mature the components are, and the specific goals. Different techniques are better suited to different phases and objectives.

Table 23: T4M validation techniques

Validation technique	Description
Workshop-Based Validation	A collaborative facilitated session where stakeholders—including developers and business users observe and interact with the system in real-time. It involves a live demonstration of key features or workflows allowing stakeholders to evaluate how the system behaves against expected outcomes. This technique encourages discussion, immediate feedback, and rapid refinement. It's particularly effective for validating interoperability between components, capturing usability concerns early, and fostering cross-disciplinary alignment.
Functional Testing	A structured technique to verify that individual features or components perform as intended when provided with defined inputs and system states. For example, checking whether an algorithm calculates the correct output based on input constraints. This aims to ensure functional correctness, input validation, and expected output generation. It is used early and iteratively throughout the development cycle.
Scenario-Based Testing	Focuses on validating the system through realistic, end-to-end workflows that simulate actual user behaviour or operational processes. Each test scenario is derived

Validation technique	Description
	from a user story or business case. This technique helps validate system integration and overall functional coherence across multiple services or components. It also reveals issues that may not surface in isolated functional tests.
Usability Testing	A user-cantered evaluation technique that observes real users completing tasks to assess how intuitive, efficient, and satisfying the user interface is. This testing helps identify UI/UX issues, measure task success rates, and gather subjective user feedback on ease of use. It's especially valuable when validating new interfaces or workflows, ensuring that the system supports a positive user experience and aligns with usability goals.
User Acceptance Testing	Conducted in the final stages of validation, UAT involves business stakeholders or end-users verifying that the software solution meets defined business requirements and user expectations. Users test predefined scenarios or freely explore features to assess whether the system is fit for purpose. Their feedback is used to confirm deployment readiness. UAT is critical for ensuring confidence that the system will function effectively in its operational environment.

2.7 Issue management strategy

This section outlines the issue management strategy for T4M project. The primary goal is to prevent defects, however when this is not possible the goal is to find them as quickly as possible and minimize their impact. The issue management strategy provides a structured strategy for identifying, documenting, tracking, and resolving issues encountered during the project lifecycle, particularly during validation and testing phases. The goal is to ensure all issues are managed consistently, transparently, and in a timely manner.

T4M follows an issue management strategy supported by an Excel-based issue tracking system (i.e., Issue Tracker) providing a centralized, easily accessible way to record, update, and monitor the status of all reported issues. It enables component owners to manage validation outcomes in a structured format that supports filtering, prioritization, and reporting. Progress is tracked and monitored on regular basis.

Table 24 outlines the procedure to be followed once an issue is identified.

Table 24: Issue reporting-resolution procedure

Step	Activity	Description	Responsible	Method/Tool
1	Issue Identification	Identifies issues during operation and validation activities and documents the issue.	Participants	Issue report template
2	Issue registering	Uploads issue report in the shared sophistry and logs issues in the issue tracking system.	Pilot Site Coordinator	Issue tracker
3	Issue notification	If the issue reporter can identify the component causing the malfunctioning, he or she sends an email to the appropriate component owner otherwise. the email is sent to the assigned Value Network Pilot	Pilot Site Coordinator	Email notification

Step	Activity	Description	Responsible	Method/Tool
		Technical Partner including link to the uploaded issue report.		
		If the Value Network Pilot Technical Partner receives a notification from the Pilot Site Coordinator, he or she sends an email to the appropriate component owner, or to multiple owners if several components are involved.	Value Network Pilot Technical Partner	Email notification
4	Issue analysis and categorisation	The reported issue is checked to verify if it corresponds to a real or perceived issue. At this stage the bug can be either rejected and the issue closed in the issue tracking system or categorised by assigning severity, and priority. At this stage, the issue can either be rejected and closed in the tracking system, or it can be categorized by assigning a severity and priority level.	Component Owner	Issue tracker
5	Issue resolution, and notification	Issues are resolved based on their priority level. The fixes are verified and deployed, and the issue is closed.	Component Owner	Issue tracker
		Affected Pilot Site Coordinators are notified that the issue has been resolved.	Component Owner	Email notification

Table 25 presents the minimum information that participants should provide when documenting an issue.

Table 25: Issue reporting template

Date	[*Date when the issue was identified.*]
Pilot site	[*Pilot site the participant belongs to*]
Issue description	[*Issue description providing as many details as possible to reproduce it .*]
Evidence	[*Provide additional evidence to support the analysis of the issue, such as screenshot.]*

Figure 13 shows the issue tracker available in the T4M internal repository.

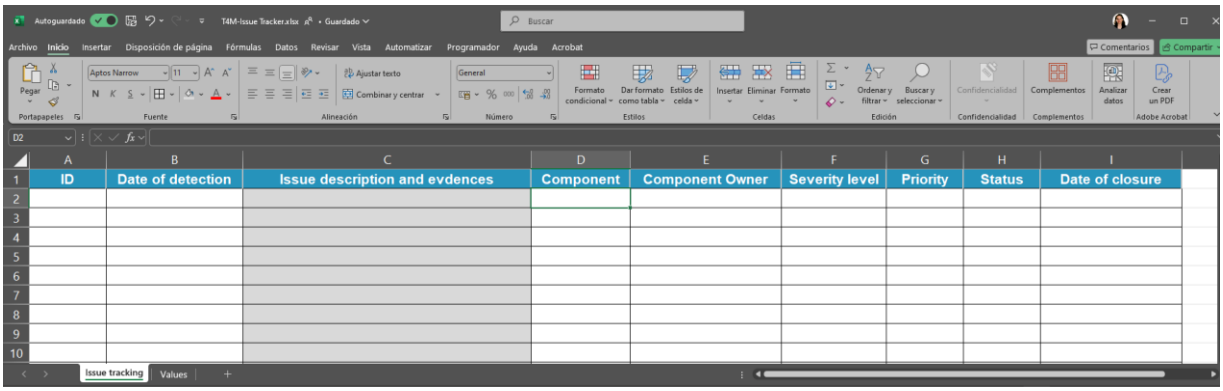

Figure 13: T4M Issue tracker screenshot - Template

The information collected for each issue and stored in the issue tracking system involves:

- **Identifier**: contains the identification of the issue. Automatically generated.
- **Date of detection**: date of reporting of the issue.
- **Issue description and evidence**: Includes the links to the uploaded information (i.e., issue report and any additional evidence).
- **Component:** includes the name of the component(s) affected by the issue.
- **Component Owner:** includes the name of the owner of the affected component.
- **Severity level**: represents the level of impact of the issue. Allowed values are: *Critical* (blocks essential operations or poses safety risks); *High* (Disrupts key functions with no acceptable workaround); *Medium* (Impacts key functions, but a workaround exists); *Low* (Causes inconvenience but does not prevent key functions); *Trivial* (Minor issues with no functional impact).
- **Priority:** indicates how urgently an issue should be addressed based on its impact. Priority for fixing bugs is based on the severity level. Low or trivial severity issues are minor and should be resolved as time permits- Allowed values are: *High* (Requires immediate attention); *Medium* (Important but not urgent); *Low* (Can be postponed and addressed later).
- **Status:** identifies the status of the issue. Allowed values are: *Open* (Issue reported and under review); *Rejected* (Issue dismissed; no action needed); *Closed* (Issue resolved and confirmed).
- **Date of closure:** date of resolution of the issue.

The Pilot Site Coordinator should complete the Issue description and evidence data; column, the rest of the information should be provided by the Component Owner. All the involved stakeholders will be briefed on the issue management procedure.

3 T4M validation preparation methodology

The validation process is driven by a comprehensive validation plan that acts as a structured roadmap for carrying out validation activities. This section introduces the methodology established within the T4M framework for developing these validation plans, which are designed to support and guide the validation phase for each iteration and Value Network Pilot. The primary objective is to provide a unified structure that ensures consistency, clarity, and alignment across all Value Network Pilots and Pilot Sites throughout the entire validation process. The methodology provides a structured framework to define the validation plans to ensure T4M meets its requirements and performs effectively. It serves as a common approach to be applied across all validation iterations, Value Network Pilots, and Pilot Sites, promoting coherence and consistency throughout the validation process. The plan begins by clearly defining the validation purpose and scope, setting the foundation for targeted and meaningful validation activities. It then guides the identification of relevant validation KPIs, which provide measurable benchmarks to assess performance and outcomes. To ensure the validation is contextually relevant and accurately executed, the methodology includes the description of the validation environment and the set-up of the validation process, tailored for each site. This also involves preparing the site infrastructure, engaging participants, and ensuring they are fully briefed and aligned. A key component of the framework is ensuring ethical and legal compliance, by verifying that all activities adhere to applicable standards and regulations. It also includes the calculation of baseline values for impact KPIs, which will serve as reference points for measuring progress. The methodology further supports the definition of a validation protocol, the identification and management of risks, and the scheduling of timelines and milestones. Define the purpose and scope of validation.

Every validation process begins by establishing its purpose and understanding *what* is being validated considering the validation iterations (i.e., initial and final) and target pilot (i.e., VN1, VN2 and VN3).

3.1.1 Validation purpose

In the context of a validation plan, the validation purpose sets the foundation for the entire process. It defines why the validation is being conducted and what it aims to demonstrate or prove. This purpose guides the planning of test activities, the selection of performance indicators, the structuring of test environments, and the interpretation of results.

At this stage it is essential to identify and document all supporting materials that provide background, requirements, or guidance relevant to the solution to be validated, the testing activities, and the broader project context. These references are typically organized into two categories: internal and external.

- **Internal references**: they include project-specific documents and artifacts that have been created and maintained within the organization. These documents provide critical information about the solution design, intended functionalities, and the basis for testing. Key internal references may include requirements specifications detailing the functional and non-functional expectations of the system, system or software design documents outlining architectural and technical design elements, user manuals providing comprehensive instructions that help end users to understand and operate the system. Each internal reference should be listed with a code or identifier, a title, and its document type to support easy retrieval.
- **External references:** they **c**onsist of documentation that originates outside the project team or organization but is still relevant to the validation process. These may include for example: applicable Laws and Regulations that the system must comply with (e.g., data protection, safety standards),

industry Standards that define best practices or mandatory protocols, user guides, installation guides, or operations manuals for third-party components or platforms integrated into the solution.

Table 26 provides a template to collect both external and internal references.

Table 26: References - template

Code	Document	Description	Comments
[Reference code]	*[Name of the specific reference document]*	*[Description of the specific reference document]*	*[Any relevant comment]*

3.1.2 Validation scope

The next step is defining what will be tested. This involves identifying the specific user stories, use cases, or system components that will be included in the current validation cycle. It is equally important to determine which elements will be excluded, based on factors such as their level of readiness, relevance to the current iteration, or overall criticality to the system's intended use. Both inclusions and exclusions must be clearly documented. For any excluded items, a clear rationale should be provided to justify why they are not part of the current validation effort.

Table 27 presents a template for documenting the user stories and T4M components that are to be included in the validation process. Table 28 provides a template to identify the user stories and T4M components that are excluded from the validation process.

Table 27: Included user stories, use cases- template

User story ID	User story scope	T4M Components
[User story /use case ID]	*[Short description and scope in the current iteration.]*	*[Involved T4M components]*

Table 28: Excluded user stories, use cases, - template

User story ID	User story scope	T4M Components	Rationale
[User story ID]	*[Complete name of the User story /use case]*	*[Involved T4M components]*	*[Rationale explaining why the user story has been excluded]*

3.2 Validation KPIs

The Identification of Validation KPIs phase is focused on defining the specific metrics that will be used to evaluate the success and performance of the solution during the validation process. This phase ensures that the assessment is objective, measurable, and aligned with both technical and strategic goals. In this phase, relevant Key Performance Indicators (KPIs) are selected based on the scope and objectives of the validation activities.

Table 29 provides a template for summarizing the selected KPIs. Specific details should be defined during the development of the validation protocol.

Table 29: Selected KPIs - template

Concept	Selected KPIs	Acceptance criteria
[User story /use case ID]	*[Complete name of the User story /use case]*	*[Rationale explaining why the user story or use case has been excluded]*

3.3 Validation environment

This phase involves providing a comprehensive description of the environment in which the system will be tested, with the goal of replicating real-world deployment conditions as closely as possible depending on the current validation iteration. This includes details about the hardware and software configurations, network architecture, integration with third-party systems, available data sources, and any other components that play a role in system operation.

To effectively communicate the system architecture and its deployment during validation, deployment diagrams are highly valuable. These diagrams provide a visual representation of how system components are distributed across physical or virtual infrastructure. They depict the relationships and interactions between services, modules, APIs, and external systems, helping all stakeholders clearly understand where and how the system operates within the validation setup. This visibility ensures that testing is aligned with actual usage scenarios and helps identify potential integration or performance issues early in the process. Each value network pilot deployment diagrams will outline the T4M components involved, specifying whether they need to be deployed locally at the factory level or can be accessed remotely. The deployment configuration may vary across validation iterations, depending on the maturity of the components and the specific objectives of each validation iteration.

3.4 Set-up validation process

Setting up the validation process involves preparing all the necessary technical and organizational elements required to carry out the validation activities effectively. This step ensures that the technical environment, human resources, and compliance obligations are fully prepared before any validation activity begins. Furthermore, it defines the baseline of the impact assessment KPIs.

3.4.1 Site infrastructure preparation

The objective is to ensure infrastructure readiness at factory level by providing the necessary hardware and software components required to deploy and operate the planned value network pilots. This includes, for example, the procurement and provisioning of the hardware infrastructure to support the deployment and operation of T4M components at the pilot site level**, either** on-premises or hosted in a private cloud infrastructure such as Microsoft Azure, AWS, or equivalent. It also involves the identification of relevant data sources (e.g., ERP, MES) at the factory level and the identification of the mechanisms for information exchange; the procurement, deployment, and configuration of third-party software required for the deployment of T4M components at factory level; and the preparation of the IT infrastructure to ensure access to the locally deployed components (e.g., factory level dataspace connectors).

Once the factory infrastructure is in place, the involved factory-level components are deployed and configured in accordance with the deployment and configuration procedures specific to each component, as detailed in their respective technical documentation.

Each Pilot Site IT representative from the value network pilot participants (i.e., ARÇELIK, KAREL, ACRON, URA, ERREKA, TEKNIKER, and AIBEL), in collaboration with their respective local Value Network Pilot Technical Partner (i.e., SmartOpt for VN1, TEKNIKER for VN2, and UIO for VN3), is responsible for carrying out the necessary activities to ensure that their infrastructure is ready for the execution of their specific pilot.

Table 30 outlines the template to collect system and software preconditions required for deploying T4M components at the Pilot Site level.

Table 30: Systema and software requirements - template

T4M Component	System requirements	Software requirements
[Name of the T4M component]	*[System requirements to deploy the component]*	*[Software that need to be installed to deploy the component]*

Table 31 presents the template to detail the preparation procedure to be followed by the Pilot Sites.

Table 31: Pilot site preparation procedure -template

Step #	Description	Reference	Pilot sites	Responsible
[Sequence number]	*[Description of the preparation activity]*	*[Reference Document]*	*[Pilot Sites where the activity is foreseen]*	*[Responsible stakeholder per Pilot Sites]*

3.4.2 Participants involvement

Participants play a crucial role in validating the functionality, usability, and overall performance of the value network pilots under realistic conditions. During the validation process, participants have the following key responsibilities:

1. Executing predefined validation test cases supporting user stories in accordance with the established validation procedures. This allows for a practical evaluation of how effectively the T4M technologies support users in realistic scenarios.
2. Providing structured feedback on various aspects of the system, including functionality, usability, responsiveness, and relevance. This feedback is collected through formal methods such as, for example, questionnaires, interviews, or focus group discussions.
3. Identifying and reporting bugs, issues, or inefficiencies encountered during operation. These observations are critical in supporting the development team to address shortcomings and implement necessary improvements.

The involvement of participants in the validation process follows a structured procedure to ensure meaningful and effective engagement, as outlined in the following subsections.

3.4.2.1 Participant Recruitment and Consent

Participants are selected based on their roles in the user stories or use cases involved in the validation process. The role and number of the involved participants for each value network pilot should be identified as described in Table 32.

Table 32: Value network participants - template

Role	Role description	Pilot Site	Quantity
[Participant role]	*[Participant role description]*	*[Name of the specific pilot site involved in the current value network]*	*[Number of involved participants]*

Each partner involved in the value network pilots is responsible for recruiting participants for the validation iterations within their respective pilot activities. Participation is entirely voluntary, based on the principle of user autonomy, and is formalized through a signed informed consent form. All selected participants will receive an information sheet that clearly outlines the purpose, and the procedures involved in the validation process along with the informed consent form including withdrawal procedure (refer to Appendix A: Brief & Informed Consent Template). Moreover, all the participants will be briefed on the issue management procedure.

Once participants have agreed to take part in the validation experiments, they will be invited to an initial presentation session. This session serves as an important introduction and preparation phase before any validation experiment begins. During the session, participants will receive a brief overview of the project's overall objectives, followed by a more detailed explanation of the specific goals of the upcoming validation process. The session also offers an opportunity to address any questions or concerns raised by participants.

3.4.2.2 Participant Training

To ensure participants are well-prepared, a dedicated training phase will be conducted prior to validation. This training aims to build familiarity with the tools or procedures used during the validation activities. These sessions will be designed to provide a comprehensive walkthrough of the T4M component or target functionality, explaining its purpose and key features.

Training will be delivered through online webinars, led by the respective component owners. Each session will be structured into two main parts: (1) a demonstration and explanation of the component or functionality, including its practical use, and (2) n interactive Question &Answer session, where participants are encouraged to raise any questions or share feedback. The training webinar will be recorded and made available afterward for consultation, so that participants can revisit the information at any time or share it with other team members involved in the validation.

The webinars are primarily intended for the following target audiences: participants who will directly interact with the components, as well as Value Network Pilot Coordinators, Pilot Site Coordinators, and technical partners responsible for supporting the pilot implementations and operation.

A series of webinars will be scheduled according to the needs identified by the Value Network Pilots in their respective Validation Plans, covering the initial and final validation iterations.

3.4.3 Ethical and legal compliance Ensure ethical and legal readiness

As described in the Data Management Plan (DMP) included in deliverable D1.3 (Data Management Plan v1) the compliance with the current legal and ethical framework related to privacy is an important part of T4M right from the beginning.

T4M is fully committed to upholding ethical standards and fundamental rights as defined by EU regulations, including the General Data Protection Regulation5 (GDPR), ePrivacy Directive[6], and national data protection laws. All personal data processing will follow strict legal and ethical guidelines, with data protection by design and by default integrated throughout the project. Only authorised data providers, with appropriate consent and legal clearance, may share personal data. This data will be pseudonymised/anonymised. Identifiable information will be stored separately and processed using neutral code to prevent attribution to individuals. Consortium partners involved in data collection and processing will act as joint data controllers. Their roles and responsibilities will be defined in a formal agreement, supported by clear, ongoing communication to ensure GDPR compliance. No personal data transfers to third parties are planned. If needed in the future, all necessary legal and technical safeguards will be put in place and documented in the final Data Management Plan. Each participant in the value network pilots must identify the personal data processed in the scope of the operation and validation activities (following template in Table 33) and describe how they are being used and managed (following template in Table 34) in compliance with the DMP.

Table 33: Processed personal data – Template

Concept	Description
Identification Data	*[Data that directly identifies a person, such as name, address, email, phone number, ID numbers (e.g., passport, national ID).]*
Health-Related Data	*[Any personal data related to the physical or mental health of an individual, including medical history, test results, diagnoses, or treatment information.]*
Other Special Categories of Data	*[Sensitive data requiring extra protection, including racial or ethnic origin, political opinions, religious or philosophical beliefs, trade union membership, genetic and biometric data, and data concerning sex life or sexual orientation.]*
Other Personal Data	*[All other data that can indirectly identify a person, such as job title, education, financial data, social media activity, images, videos, voice recordings, opinions or behavioural information.]*
Location Data	*[Data that indicates the geographic position of an individual, including GPS data, mobile location tracking, or IP address-based location.]*

Table 34: Use and management personal data– Template

Concept	Description
Personal data purpose,	*[Define the primary purpose for collecting the identified personal data.]*
Personal data additional use	*[Define any other use of data collected.]*
Personal data producer	*[Identify who produces the data.]*
Personal data storage	*[Identify who stores the data.]*
Personal data sharing	*[Identify with whom the data will be shared.]*
Data Controller (DC)	*[Identify the person who determines the purposes for which and the way any personal data are, or not, to be processed.]*

[5] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0679
[6] Directive - 2002/58 - EN - eprivacy directive - EUR-Lex

Concept	Description
Data Processor (DP)	*[Identify the person in charge of the analysis of the data collected during the validation to prepare the test case evaluation results.]*

3.4.4 Impact KPIs baseline calculation

Before meaningful validation can take place (i.e., during the final validation cycle), it is essential to establish a baseline for the key performance indicators (KPIs) that will be used to assess the impact of T4M in relation with all the value network pilots. These baselines represent the "as-is" performance levels before T4M results are introduced for validation and provide a clear and measurable reference point against which potential impact can be identified and quantified.

3.5 Validation protocol

The purpose of the validation protocol is to define a clear and replicable procedure for describing, conducting and documenting experiments during the validation process. It ensures that all experimental activities are aligned with validation objectives and scope, support the measurement of defined KPIs, and are carried out consistently across all Value Network Pilots and Pilot Sites.

The validation protocol begins with the description of the test techniques and tools selected based on the nature of the system and validation requirements. The protocol then outlines the approach for defining validation test cases, specifying the actions to be performed, the roles involved, the success criteria, and the metrics used to assess performance and outcomes. It also provides guidance on data collection and documentation, identifying the types of data to be gathered during testing and the expedite deliverables. Finally, the protocol establishes test completion and retesting criteria, providing clear conditions for determining when testing can be considered complete.

3.5.1 Test techniques

The focus is on selecting the most appropriate test techniques (e.g., user acceptance testing, usability testing, , performance testing, etc.). Techniques and tools are mapped to the validation tests cases to ensure consistency and clarity during execution.

Table 35 provides the template to identify the test techniques foreseen in the current validation iteration.

Table 35: Test techniques- Template

Test technique name	Description
[Name of the test technique	*[Description of the test technique]*

3.5.2 Validation test cases

This activity focuses on developing clear and structured validation test cases to evaluate whether the system or its components meet user needs in a realistic context. It involves translating user stories or system functionalities into specific test scenarios that can be executed during the validation phase.

Core functionalities share common validation test cases. Each Value Network Pilot should define validation test cases aligned with the specific user stories or system components involved in the current validation iteration.

Table 36 represents a template to define validation test cases in the framework of T4M.

Table 36: Validation test case definition - template

10	Description
Validation Test Case ID	*[A unique identifier for the test case (TC#.Iteration for common test cases or , VN#.TC#.Iteration for VN specific test cases).]*
Test Title	*[A concise title that summarizes the purpose or focus of the test case.]*
Test Techniques	*[A concise title that summarizes the purpose or focus of the test case.]*
Related User Story	*[Reference to the specific user story that the test case is validating.]*
T4M Component	*[Reference to the specific T4M component or components flow that the test case is validating.]*
Test Objective	*[The primary goal of the test, explaining what aspect of the system is being validated (e.g., functionality, usability).]*
Preconditions	*[Conditions or setup required before the test can be executed]*
Participant role/quantity	*[The role(s) and quantity of individuals involved in the test.]*
Test Steps	*[A clear, step-by-step guide for executing the test case, written in sequential order.]*
Observation	*[Any relevant observation elated to the validation test case.]*
KPIs (1-N)	
KPI	*[The specific metrics used to measure the test objective]*
Measurement method	*[The specific procedure or technique used to collect data during testing (e.g., questionnaires, system logs, performance tools).]*
Calculation method	*[The specific formula or process applied to analyse collected data and derive meaningful results or metrics.]*
Success criteria	*[The specific conditions that define a test as successful by confirming the system meets expected behaviour.]*

3.5.3 Test completion and retesting criteria

This involves defining clear criteria to determine when testing is complete, ensuring that all planned tests have been executed and objectives met before closing the test phase. It includes planning for retesting cycles, which are triggered when issues are found or changes are made, to confirm fixes and maintain system stability.

3.6 Risk management

Effective management of risks is a critical component of the validation process, ensuring that the planned activities are executed smoothly and deliver reliable results. This strategy outlines how risks are systematically identified, assessed, mitigated, and monitored across the validation iterations, with clear responsibilities assigned to relevant stakeholders.

The validation risk management strategy includes four main steps:

1. **Risk Identification**: Potential risks are identified early in the planning phase, covering technical, organizational, procedural, and user-related areas.

2. **Risk Assessment**: Each risk is evaluated based on its **Likelihood (L)**, **Impact (I)**, and **Exposure (E = L × I)** to prioritize them.
    - **Likelihood (L)**: How probable is it that the risk will occur?
    - **Impact (I)**: If the risk occurs, how severe will the consequences be?
    - **Exposure (E)**: how much a particular risk could affect the project if it happens. It's a combination of two important factors:

    Exposure = Likelihood x Impact

    The scales for both probability and impact will be 1-5, where 5 is the highest. Based on this assessment, risks are prioritized using a simple scale (e.g., low, medium, high). This helps to focus on the most critical issues first
3. **Mitigation Planning**: For each high or moderate risk, specific mitigation actions are defined to reduce either the probability or impact of occurrence.
4. **Monitoring and Updating**: Risks and mitigation actions are reviewed regularly throughout the validation iteration. New risks may be added, and existing risks updated or closed as needed.

Risks and their associated mitigation actions are reviewed on a regular basis as part of pilot coordination meetings or progress reviews. During these sessions newly emerging risks are added, and unresolved or escalating risks are flagged for additional support or intervention. Each VN Pilot Coordinator is responsible for managing pilot related risks and communicating significant risks to the Operation and Validation Leader-

Table 37 provides the template to define the risk management plan.

Table 37: Risk management - Template

Risk Id	Risk Description	L	I	E	Mitigation activity
[ID of the identified risk] R.VN#.Iteration#.	*[Description of the identified risk]*	*[L value]*	*[I value]*	*[E value]*	*[Description of the mitigation activity]*

3.7 Schedule timeline and milestones

The objective of this phase it to provide a structured and time-bound roadmap for executing the validation activities. This step translates the validation strategy into an actionable plan by identifying key phases, setting clear start and end dates, and outlining major milestones and deliverables.

Table 37 provides the template to define the validation schedule.

Table 38: Validation schedule - Template

Phase	Activity Description	Start Date	End Date I	Milestone / Deliverable	Responsible	Remarks / Dependencies
[Identification of the phase]	*[Brief explanation of the specific*	*The date on which the activity is*	*[The date by which the activity is expected to*	*[Key output or checkpoint that marks the successful*	*[Stakeholder accountable for executing or*	*[Notes on prerequisites, linked tasks, or factors that may affect execution.]*

Phase	Activity Description	Start Date	End Date I	Milestone / Deliverable	Responsible	Remarks / Dependencies
	action to be carried out.]	*planned to begin*	*be completed.]*	*completion of the activity]*	*leading the activity.]*	

4 Validation Plan: first validation iteration

The first validation iteration (June–November 2025) tests an early version of the T4M solution, focusing on core features aligned with project goals. It aims to assess usability, functionality, and performance in real-world scenarios. This early testing, involving end users, helps identify issues and gather feedback to guide improvements in future development cycles. To support this process, this section presents the initial validation plans for each of the three Value Networks (VN1, VN2, and VN3). Each plan is tailored to the specific industrial context and technological scope of the respective pilot, detailing the purpose, scope, selected KPIs, validation environment, test protocols, risk management strategies, and activity timelines.

As the initial validation iteration focuses on core functionalities shared across all Value Networks, the common validation test cases have been consolidated and moved to Appendix C for improved readability. Each Value Network's validation plan now includes only the test cases specific to its unique context and components.

4.1 VN1 validation plan

4.1.1 Purpose and scope

4.1.1.1 Validation purpose

The first validation iteration for VN1 is focused on evaluating initial prototypes of the T4M components that support electronic board supply chain operations. At this stage, core functionalities for provider/consumer onboarding, demand forecasting analytics, and basic procurement workflows are available for testing. The included features represent foundational capabilities designed to demonstrate initial integration between system components and enable basic data exchange between electronic board providers and consumers.

Table 39: Validation: Initial iteration - VN1 Pilot- Internal References

Code	Document	Description	Comments
D2.1	Reference cases and actionable models for reconfigurable value networks and service decomposition v1	Describes Value Network 1 use case stories and related use cases	Initial version
D2.5	Tech4MaaSEs architecture blueprint and specifications v1	Outlines T4M components and their interactions in Value Network 1 via sequence diagrams	Initial version
DSC.IM	Dataspace Connector installation manual and software release	Outlines the deployment procedure and includes access to the latest release	Initial version. To be provided by TEKNIKER
DSC.CM	Reference cases and actionable models for reconfigurable value networks and service decomposition v1	Outlines the configuration procedure	Initial version. To be provided by TEKNIKER
DSC.UM	Tech4MaaSEs architecture blueprint and specifications v1	Provides clear instructions on how to operate the component	Initial version. To be provided by TEKNIKER

No external references are foreseen for VN1 in the first validation iteration.

4.1.1.2 Validation scope

Given the purpose of this first iteration and the readiness of the T4M components, only a subset of VN1 user stories is included for initial testing. The validation focuses on core onboarding processes and basic electronic board procurement workflows.

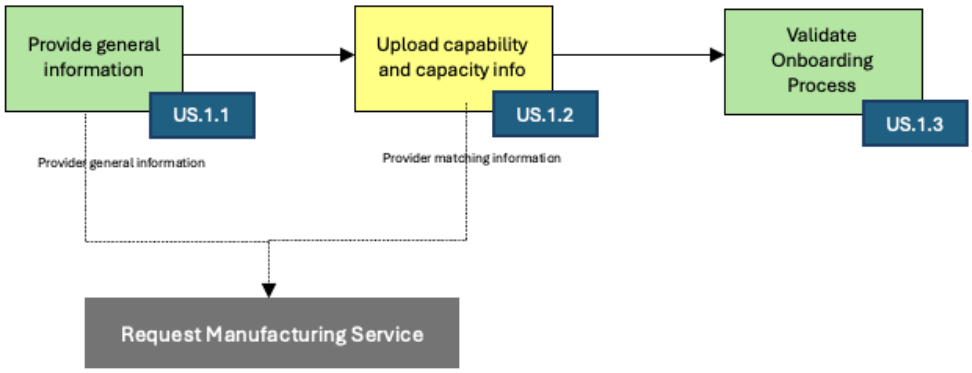

Figure 14: Validation: Initial iteration - VN1 Providers' onboarding process coverage

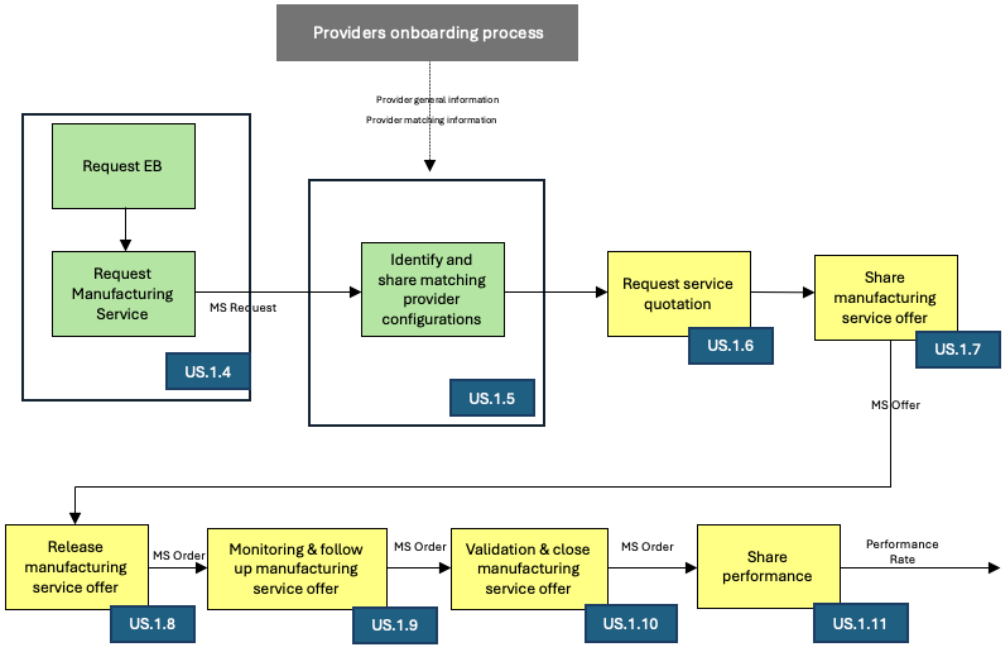

Figure 15: Validation: Initial iteration - VN1 Request Manufacturing Service

Table 40: Validation: Initial iteration – VN1 Included user stories, use cases

User story ID	User story	T4M Components
US0.1	*"As a Super-User, I want to create, update, and delete user roles and user accounts through the User Interface, so that I can manage access permissions and maintain up-to-date user data within the Tec4MaaSEs system."*	User management
US0.4	*"As a user, I want to activate my account, log in, update my account details, and log out via the Tec4MaaSEs User Interface, so that I can securely access and*	User management

User story ID	User story	T4M Components
	manage my account within the platform. This applies to both MaaS consumers and MaaS providers." T4M's users manage their accounts through a secure process that includes activation, login, profile updates, and logout. Users activate their accounts via an email link, setting a password through the UI, which is verified by the User Management component. After activation, users log in with their credentials, receiving access and refresh tokens upon successful authentication. They can update account details via the UI, with changes verified and applied by User Management. Logging out ends the session securely, with the UI redirecting the user appropriately. This flow ensures secure and user-friendly access management on the platform. **For the first validation iteration initial version of the core functionalities such as account activation, log in, update account details, and log out are available however organization the verifiable credentials are not yet considered.**	
US1.1	*"As a Provider/Consumer, I want to register/sign up my organization to enable manufacturing as a Service Production of EBs"*	Organization Management
US1.3	"*As T4M, I want to check the information that the Provider/Consumer has entered for validation*"	Organization Management
US1.4	"*As a Planning Department representative, I want to request a manufacturing service*"	Search & Match
US1.5	T4M wants to extract the manufacturing service requirements and match eligible provider configurations. **For the first validation iteration an initial version of all the core features of getting the manufacturing service requirement (organization management) is ready for validation. In the final iteration it is planned to enhance this core functionality with the full functionality. Search & Match for matching eligible provider configuration will be validated in the final iteration for electronic boards.**	Search & Match, Organization Management

For the first validation iteration, initial versions of the core features supporting provider/consumer registration, data validation and basic electronic board request processing are ready for validation. Advanced features such as negotiation, real-time monitoring, and performance assessment will be included in the final iteration.

Table 41: Validation: Initial iteration – VN1 Excluded user stories, use cases

User story ID	User story	T4M Components	Rationale
US1.2	*"As T4M, I want the consumer's/provider's IT representative to provide me secure access to information about capabilities and capacities"*	Organization Management, Dataspace Connector	Partially supported but not validated in current iteration. Included in final iteration

User story ID	User story	T4M Components	Rationale
US1.6	*"As Planning Department I want to get the scoreboard of proposed configurations to request quotations"*	Supply Chain Monitoring	Partially supported but not validated in current iteration. Included in final iteration
US1.7	*"As Planning Department I want to release service quotations"*	Supply Chain Monitoring, Predictive / Proactive Analytics/Forecasting	Partially supported but not validated in current iteration. Included in final iteration
US1.8	*"As Consumer/Provider I want a facilitator for information exchange and negotiation"*	Supply Chain Monitoring	Partially supported but not validated in current iteration. Included in final iteration
US1.9	*"A As Consumer/Provider I want a facilitator for order follow-up"*	Supply Chain Monitoring	Not supported in current iteration. Included in final iteration
US1.10	*"As Consumer/Provider I want to communicate with all value network members"*	Supply Chain Monitoring	Not supported in current iteration. Included in final iteration
US1.11	*"As Consumer/Provider I want to provide performance assessment"*	Balanced Scorecard, Organization Management	Not supported in current iteration. Included in final iteration

4.1.2 Validation KPIs

Table 42: Validation: Initial iteration – VN1 KPIs

Concept	Selected KPIs	Acceptance criteria
Functional Suitability	Functional correctness rate (%)	>=95%
Usability	Number of usability issues (units)	<=5 issues per component
	Perceived usability (qualitative in % + qualitative)	>=80 for quantitative values
Performance	Response time (seconds)	<5 seconds for data queries
	Number of critical defects	=0

4.1.3 Validation environment

During the first validation iteration, no factory-level components will be deployed at the Pilot Sites. All T4M components (User Management, Organization Management, Search & Match) will be accessed remotely through web interfaces. The Digital Twin component, while included in the architecture, will operate with simulated data rather than real-time factory connections.

4.1.4 Set-up validation

4.1.4.1 Site infrastructure preparation

The objective is to ensure infrastructure readiness of the Pilot Sites to proceed with the validation activities. Table 43 describes the system and software preconditions for the deployment of T4M components at Pilot Site level.

Table 43: Validation: Initial iteration – VN1 Pilot- Systema and software requirements

T4M Component	System requirements	Software requirements	Responsible
All components (User Management, Organization Management, Search & Match)	Modern web browser (Chrome, Firefox, Edge), stable internet connection	No local software installation required	--

Table 44: Validation: Initial iteration – VN1 Pilot site preparation procedure

Step #	Description	Pilot sites	Responsible
1	Ensure stable internet connection	ARCELIK, KAREL, ACRON	Pilot Site IT Representative
2	Verify browser compatibility	ARCELIK, KAREL, ACRON	Pilot Site IT Representative
3	Create test user accounts	ARCELIK, KAREL, ACRON	Pilot Site Planning Representative

4.1.4.2 Participants involvement

4.1.4.2.1 Participant Recruitment and Consent

The following table identifies the participants to be involved in initial validation iteration.

Table 45: Validation: Initial iteration – VN1 Participants

Role	Role description	Pilot Site	Quantity
Administration representative	Person acting on behalf of a company to register it into T4M. Registers the company with the selected role(s).	ARCELIK	1
		KAREL	1
		ACRON	1
Planning Department representative	Person acting as a representative of the planning department.	ARCELIK	1
		KAREL	1
		ACRON	1
IT/Technical representative	Person with technical background supporting system configuration and data preparation for validation activities.	ARCELIK	1
		KAREL	1
		ACRON	1

All the participants will receive an information sheet that clearly outlines the purpose and the procedures involved in the validation process along with the informed consent form including withdrawal procedure (refer to Appendix A). The informed consent will be provided in both English and Turkish language.

Once participants have agreed to take part in the validation experiments, they will be invited to an initial presentation session introducing the project's overall objectives, followed by a more detailed explanation of the specific goals of the upcoming experiment. Moreover, participants will receive a briefing on the issue

management procedure, along with clear instructions on how to complete the issue reporting template and use the issue tracker effectively.

4.1.4.2.2 Participant Training

To ensure participants are adequately prepared, a series of training activities will be carried out prior to the start of the validation phase. The webinars will be recorded and made available for future reference. Table 46 identifies a set of webinars relevant to support the operation of VN1 Pilot.

Table 46: Validation: Initial iteration – VN1 Training activities

Webinar	Objective	Responsible	T4M Components involved
Getting started with T4M	Explain how to create users and register organizations as electronic board providers or consumers in T4M platform. Provide examples for the registration process.	ATC	User Management, Organization Management
Electronic Board Request Management	Explain how to place an electronic board manufacturing request. Provide examples for different types of electronic boards.	ATC	Search & Match

4.1.4.3 Ethical and legal compliance Ensure ethical and legal readiness

Table 47 identifies the personal data processed in the scope of the operation and validation activities for VN1 Pilot.

Table 47: Validation: Initial iteration - VN1 Processed personal data

Concept	Description
Identification Data	Participants will be identified using a unique code in the format ParticipantID (ID_Site_Number). Only the Pilot Site Coordinator will have access to personal identification details (such as name and institutional email address), strictly for coordination purposes. When referenced in results or documentation, participants will be identified only by their ParticipantID.
Health-Related Data	Not applicable — no health-related data will be collected.
Other Special Categories of Data	Not applicable — no sensitive personal data (e.g., racial or ethnic origin, political opinions, religious beliefs, etc.) will be processed.
Other Personal Data	Personal opinions related to usability may be collected during experimentation. Additionally, screen recordings are used, but without capturing voice or identifiable personal content. The usability interviews will not be recorded. In specific, consented cases, photos or interview recordings may be taken strictly for dissemination purposes, and only with prior explicit consent as outlined in the informed consent form signed by participants.
Location Data	No direct location data will be recorded. Only participants' institutional affiliation (e.g., organization or pilot site) will be collected.

Table 48 describes how the collected personal data are being used and managed in the framework of VN1 Pilot.

Table 48: Validation: Initial iteration - VN1 Use and management personal data

Concept	Description
Personal data purpose,	Carry out the first validation iteration according to the validation plan and test cases and gather relevant feedback to support further improvements.
Personal data additional use	Photos or video recordings may be shared for dissemination purposes, as specified in the signed informed consent.
Personal data producer	Participants from ARCELIK, KAREL, and ACRON involved in the validation.
Personal data storage	Any personal data to be stored will include only the ParticipantID. Personal data already available at Pilot Site level follows site internal rules fully compliant with privacy and data protection policies.
Personal data sharing	Photos or video recordings may be shared for dissemination purposes, as specified in the signed informed consent.
Data Controller (DC)	Pilot Site Data Controller. A specific DC is nominated for each pilot site (i.e., ARCELIK Romania, ARCELIK Bolu, KAREL, ACRON)
Data Processor (DP)	Person in charge of the analysis of the data collected during the experimentation to prepare the test case evaluation results.

4.1.4.4 Impact KPIs baseline

The first validation iteration does not include the measurement of impact KPIs or their baseline

4.1.5 Validation protocol

The purpose of the validation protocol is to define a clear and replicable procedure for describing, conducting and documenting experiments during the validation process. It ensures that all experimental activities are aligned with validation objectives and scope, support the measurement of defined KPIs, and are carried out consistently across all Pilot Sites.

4.1.5.1 Test Techniques

Table 49 introduces the test techniques foreseen in the first validation iteration.

Table 49: Validation: Initial iteration – VN1 Test techniques

Test technique name	Description
Workshop-Based Validation	Live, collaborative sessions where stakeholders observe system behavior with realistic data.
Functional Testing	Verifies that individual features or components work correctly with defined inputs and outputs.
Scenario-Based Testing	Tests end-to-end workflows based on real user stories to validate integration and overall system behavior across components.
Usability Testing:	Involves observing real users performing tasks to identify interface issues and evaluate user satisfaction and efficiency.

4.1.5.2 *Validation test cases*

The validation test cases for VN1 involve only core functionalities.

Table 50: Validation: Initial iteration – VN1 Validation tests cases summary

Validation test case	Description	User story Covered	Reference
TC.01.1	User and Role Management Functionality Validation	*US0.1*	Appendix C
TC.01.2	User Account Access and Management Validation	*US0.4*	Appendix C
TC.03.1	Consumer organization registration	US1.1, US1.3	Appendix C
TC.05.1	Manual Search and Filtering of Manufacturing Service Providers	US1.5	Appendix C
VN1.TC.01.1	Provider organization registration	US1.1, US1.3	Section 4.1.5.3
VN1.TC.01.2	Electronic Board Request Creation	US1.4	Section 4.1.5.3

4.1.5.3 VN1 specific validation test cases

Table 51: Validation: Initial iteration - VN1.TC.01.1

Concept	Description
Validation Test Case ID	**VN1.TC.01.1**
Test Title	Provider organization registration
Test Techniques	Scenario-Based Testing, Usability Testing
Related User Story	US1.1, US1.3
T4M Component	Organization Management,
Test Objective	Validate organization registration data and storage. Assess the usability of GUI. Functional Testing, Form Validation, UI Workflow Testing, Data Integrity Testing
Preconditions	• The Administration Representative has access to the onboarding interface (e.g., web UI) and has logged in. • No existing registration for the same organization. • All system services related to Consumer registration are operational.
Participant role/quantity	Administration representative
Test Steps	1. Navigate to the organization registration wizard. 2. Input general organization information 3. Specify logistics preferences, e.g. target shipping location(s). 4. Upload required documents (e.g., certifications, company profile if applicable). 5. Review all entered information and submit the registration. 6. Confirm receipt of a success notification. 7. Attempt to re-register the same organization to verify duplication checks.

Concept	Description
Observation	• If the Administration Representative is not related to an organization, they should only be able to see the organization registration wizard after logging in. • Each step in the wizard should validate required fields before proceeding. • Field validations (e.g., mandatory fields, format constraints) should be enforced consistently. • The system must prevent duplicate registrations based on key identifiers. • After submission, the registration should be stored correctly and trigger any downstream validation/approval workflows. • User feedback should be clear and guide correction of errors if input is invalid.
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0

Table 52: Validation: Initial iteration – VN1.TC.02.1

Concept	Description
Validation Test Case ID	**VN1.TC.02.1**
Test Title	Electronic Board Request Creation
Test Techniques	Scenario-Based Testing, Functional Testing, Usability Testing
Related User Story	US1.4
T4M Component	Search & Match, Organization management
Test Objective	Validate submission of Electronic Board Request and assess GUI usability. Functional Validation, Form Validation, UI Workflow Validation, Data Integrity Validation
Preconditions	• Consumer organization registered. • User login. • All system services related to service requests are operational.
Participant role/quantity	Procurement/planning representative
Test Steps	8. Participant Logs in 9. Participant access manufacturing request option 10. Participant enters the requested information depending on the selected type. 11. Participant submits request.
Observation	The process should be repeated for at least 10 requests for Electronic Boards (at least 50% of them includes mix of EB's). The requests should involve a representative set of components and their relative count.

Concept	Description
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0

4.1.5.4 Test completion and retesting criteria

4.1.5.4.1 Test completion criteria

In the first validation iteration, test completion is achieved once all planned test cases for the limited set of features and user stories are executed. Emphasis is placed on verifying the core functionalities critical to this early prototype phase, ensuring they meet predefined acceptance criteria without any unresolved critical defects. Throughout testing, detailed documentation captures the results of each case, including any failures or blockers encountered. Issues are managed following T4M issue management procedure.

4.1.5.4.2 Retesting criteria

Retesting is carried out primarily to verify fixes for identified defects and to confirm that changes have not adversely affected existing functionality. When defects are resolved, associated test cases are re-executed. any tests previously blocked by environmental or dependency issues are completed once conditions allow. Additionally, if any significant improvement related to the defined test cases is deployed during the validation iteration the associated test cases should be re-executed,

4.1.6 Risk management

Table 53 presents the key risks identified and the mitigation activities put in place.

Table 53: Validation: Initial iteration – VN1 Risk management

Risk Id	Risk Description	L	I	E	Mitigation activity
VN1.1.R1	Low availability or engagement of pilot users	2	4	8	Involve participant early and provide information on the purpose of the validation as well as training sessions.
VN1.1.R2	Failure to meet minimum number of test participants	2	4	8	Identify and commit participants early; have backup users identified.
VN1.1.R3	Misunderstanding of validation objectives or procedures by participants	2	3	6	Include goals and procedures overview in presentation and training sessions. S
VN1.1.R4	Participants are not sufficiently trained to use the components being validated	3	4	12	Conduct training webinars and share recorded sessions for later review. See section
VN1.1.R5	Validation timeline not aligned with availability of key staff	3	4	12	Create detailed timeline as part of the validation plan and confirm availability with stakeholders.

Risk Id	Risk Description	L	I	E	Mitigation activity
VN1.1.R6	Inaccurate or incomplete logging of issues during validation	2	3	6	Brief all participants on usage of the issue reporting template and issue tracker prior to start the validation phase.
VN1.1.R7	Incomplete or unclear validation plans at VN Pilot and Pilot site level.	3	3	9	Provide a validation protocol. See section 4.1.5
VN1.1.R8	Data collection issues during validation activities	3	3	9	Define data formats/tools early and appoint responsible persons as part of the test case definition in the validation plan.

4.1.7 Schedule timeline and milestones

This section presents the timeline and key milestones for the initial validation iteration of the VN1 pilot.

Table 44: Validation: Initial iteration – VN1 Validation schedule

Phase	Activity Description	Start Date	End Date I	Milestone / Deliverable	Responsible	Remarks / Dependencies
Preparation	Finalization of validation plan and test case definitions	June 2025	June 2025	Internal validation plan approved	SmartOpt, KAREL, ARCELIK, ACRON	Validation strategy and Validation Preparation Methodology ready
Environment Setup	Deployment of pilot environment at TEKNIKER	July2025	August 2025	Pilot site operational	SmartOpt	Enables early testing of T4M components and potential problems during deployment
Training & Onboarding	Training sessions for participants on T4M tools and validation procedures	August 2025	Sept 2025	Training completed	SmartOpt Component Owners	Webinars recorded and shared for reuse
Validation Execution	Execution of test cases at TEKNIKER	July 2025	Nov 2025	Test results collected	SmartOpt	First iteration validation plan ready
Validation Execution	Execution of test cases at KAREL, ACRON	Sept 2025	Nov 2025	Test results collected	KAREL, ACRON	First iteration validation plan ready

Phase	Activity Description	Start Date	End Date I	Milestone / Deliverable	Responsible	Remarks / Dependencies
Analysis & Reporting	Consolidation and analysis of validation results	Nov 2025	Dec 2025	Input to D5.2 – Pilots Execution and Evaluation v1	SmartOpt, ARCELIK, KAREL, ACRON	Requires complete data from all pilot sites

4.2 VN2 Validation plan

4.2.1 Purpose and scope

4.2.1.1 Validation purpose

The first validation iteration is centred around the evaluation of initial prototypes of the T4M components. At this stage, only a limited subset of features is available, with the primary focus on early functional, usability and performance testing rather than comprehensive system validation. The included features represent some core or foundational functionalities, designed to demonstrate initial integration of some of the components and enable basic interactions between components.

Table 54: Validation: Initial iteration - VN2 Internal References

Code	Document	Description	Comments
D2.1	Reference cases and actionable models for reconfigurable value networks and service decomposition v1	Describes Value Network 2 use case stories and related use cases-	Initial version.
D2.5	Tech4MaaSEs architecture blueprint and specifications v1	Outlines T4M components and their interactions in Value Network 2 via sequence diagrams	Initial version.
AMG.UM	AAS Model Generator User manual	Provides clear instructions on how to operate the component effectively and safely.	Initial version
DSC.IM	Dataspace Connector (including AAS extension) installation manual and software release.	Outlines the deployment procedure and includes access to the latest release in the form of a Dockerfile.	Initial version.
DSC.CM	Dataspace Connector (including AAS extension) configuration manual.	Outlines the configuration procedure.	Initial version.
DSC.UM	Dataspace Connector (including AAS extension) user manual	Provides clear instructions on how to operate the component effectively and safely.	Initial version.
UM.UM	User management user manual	Provides clear instructions on how to operate the component effectively and safely.	Initial version.
OM. UM	Organization Management user manual	Provides clear instructions on how to operate the component effectively and safely.	initial version.

Code	Document	Description	Comments
SM. UM	Search and Mach user manual	Provides clear instructions on how to operate the component effectively and safely.	initial version.

Table 55: Validation: Initial iteration - VN2 External References

Code	Document	Description	Comments
FA³ST.IM	FA³ST Service (AAS Server) installation manual and software release.	Outlines the deployment procedure and includes access to the latest release in the form of a Dockerfile.	Access link
FA³ST .CM	FA³ST Service (AAS Server) configuration manual.	Outlines the configuration procedure.	Access link

4.2.1.2 Validation scope

Given the purpose of this first iteration and the readiness of the T4M components and supported functionalities, only a limited set of use stories ready for some initial testing is included at this early stage. Table 56 lists the user stories that are partially or fully addressed in the current validation iteration, while Table 57 outlines those that are excluded. Use case story details for US2.O1 to US2.O3 and US2.P1 to US2.P8 are available in D2.1.

Figure 16 and Figure 17 illustrate the user stories addressed by the validation process. User stories that are fully or partially covered in the first validation iteration are highlighted in green, while those reserved for the final iteration are marked in yellow.

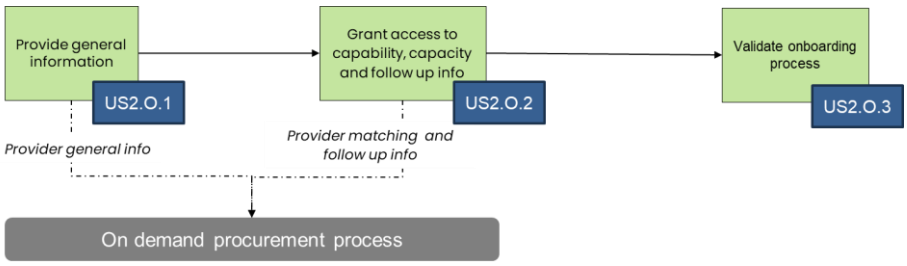

Figure 16: Validation: Initial iteration - VN2 Provider onboarding process coverage

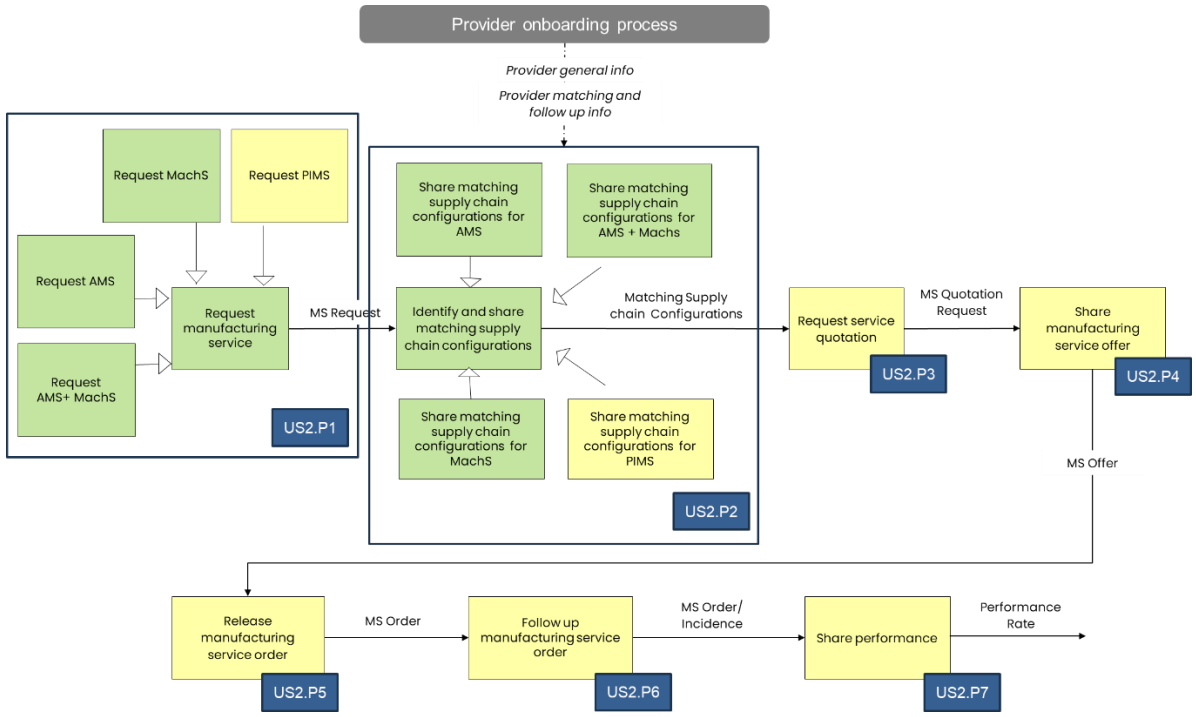

Figure 17: Validation: Initial iteration - VN2 On Demand procurement process coverage

Table 56 provides further details on the scope of the validation process for each user story included in the first iteration and identifies the related T4M components along with their implementation status and readiness level.

Table 56: Validation: Initial iteration - VN2 Included User stories and T4M components

User story ID	User story description	T4M Components
US0.1	*"As a Super-User, I want to create, update, and delete user roles and user accounts through the User Interface, so that I can manage access permissions and maintain up-to-date user data within the Tec4MaaSEs system."*	User management
US0.4	*"As a user, I want to activate my account, log in, update my account details, and log out via the Tec4MaaSEs User Interface, so that I can securely access and manage my account within the platform. This applies to both MaaS consumers and MaaS providers."* T4M's users manage their accounts through a secure process that includes activation, login, profile updates, and logout. Users activate their accounts via an email link, setting a password through the UI, which is verified by the User Management component. After activation, users log in with their credentials, receiving access and refresh tokens upon successful authentication. They can update account details via the UI, with changes verified and applied by User Management. Logging out ends the session securely, with the UI redirecting the user appropriately. This flow ensures secure and user-friendly access management on the platform. **For the first validation iteration initial version of the core functionalities such as account activation, log in, update account details, and log out are available however organization the verifiable credentials are not yet considered.**	User management

User story ID	User story description	T4M Components
US2.O1	*As a Sales Representative of a potential provider, I need a step-by-step wizard that collects all the mandatory information required for registration, including details about our manufacturing services catalogue and the countries we ship to, so that I can securely register my organization as a provider of assets and capabilities offered as-a-service.* An authorised representative can initiate the organisation's registration as a MaaS Provider (and/or MaaS Consumer) through the user interface of the Organization Management component. Once submitted, the system validates the information to ensure all mandatory fields are properly completed. If the data is valid, it is securely stored, completing the registration process. **For the first validation iteration an initial version of all the core features of the Organisation management component is ready for validation.**	Organisation management
US2.O2	*"As T4M, I want the provider's IT representative to provide me secure access to sensitive information about assets and capabilities, so that I can make these assets and capabilities available on an as-a-service basis. "* To register a new MaaS Provider in the T4M platform, manufacturing resources must be represented as digital twins using the AAS standard. A provider representative uses the AAS Model Generator to create these twins via a guided, semi-automated workflow. **For the first validation iteration, the AAS models for manufacturing resources contain only static information describing the manufacturing capabilities of both additive manufacturing and machining resources. Dynamic data, such as capacity, will be introduced in the final version along with the Data Imputer. Additionally, both capability and capacity data for plastic injection mould manufacturing will be available for the final validation phase.** Once the digital twins of the manufacturing resources are created, they onboarded by defining their data offerings. The Data Space Connector includes an AAS extension to allow users to select the target AAS model and automatically create datasets at asset level (e.g., manufacturing resources), sub model level (e.g., capabilities and capacities) or even sub model element level. These offerings are published as catalogue entries in the factory-level Data Space Connector, where usage policies can be configured to ensure secure data exchange. **For the first validation iteration an initial version of all the core features of the Dataspace Connector supporting data offering generation from an AAS model including the capabilities of an additive manufacturing or machining manufacturing resource is ready for validation.**	AAS Model Generator Dataspace Connector _____ Data Imputer (*in final iteration*)
US2.O3	*"As T4M, I want to check the information that the provider has entered, so that I can validate the completeness of the provider's registration phase and inform the provider's sales representative that they are eligible to receive new manufacturing service requests. "* Once the provider completes the onboarding procedure, the Organization Management component automatically sends a request to retrieve the capability data described in the manufacturing resource digital twins deployed at the	Organisation management Dataspace Connector Digital Twin _____

User story ID	User story description	T4M Components
	provider's site. This request navigates through the data space, involving both the T4M and Factory Level Data Space Connectors. If successful, the retrieved capability data is stored in the internal repository of the Organization Management component. **For the first validation iteration, an initial version of the core features enabling the negotiation process between the T4M and Factory Level Data Space Connectors to retrieve capability data will be available. The workflow involving interactions between Organization Management ⇆ T4M Data Space Connector ⇆ Factory-Level Data Space Connector ⇆ Digital Twin—is supported** **The Identity Provider and Vocabulary Provider components will be introduced in the final iteration.**	Identity Provider (*in final iteration*) Vocabulary Provider (*in final iteration*)
US2.P1	*"As a procurement representative I want a step-by-step wizard which prompts for input data describing product and process requirements because I want to place a request for a manufacturing service. "* A representative from an organisation registered as a MaaS Consumer can initiate and submit a Manufacturing Service (MS) Request via the user interface of the Search & Match component. This interface dynamically adapts to capture all necessary details based on the type of service requested. **For the first validation iteration an initial version of all the core features of the Search & Match component supporting additive manufacturing and machining services request is ready for validation. Plastic injection moulding services will be included in the final version.**	Search & Match
US2.P2	*"T4M wants to extract the manufacturing service requirements and then match eligible supply chain configurations because a ranked list of the supply chain configurations should be returned to the procurement representative "* For manufacturing services requests (MS Request involving Additive Manufacturing Services (AMS) or Machining Services (MachS), the relevant product and process requirements are automatically extracted using the Bill of Processes Generator. All submitted information, including the MS Request and associated requirements, is securely stored in the Search & Match's data repository, ensuring persistent availability. The Search & Match component then identifies the manufacturing resources that fulfil the requirements specified in the MS Request (i.e., capable manufacturing resources). To do this, it queries the Search & Match data repository for capability data related to resources offering the requested services and selects those that meet the criteria. Once the suitable resources are identified, the component proceeds to request an estimation of processing times from the Bill of Processes Generator. **For the first validation iteration an initial version of all the core features of the Bill of Processes Generator, including both data extraction and processing time estimation, is ready for validation. The workflows involving interactions between Search & Match ⇆ Bill of Processes Generator; Search & Match ⇆ Organization Management ⇆ Bill of Processes Generator are supported.**	Search & Match Bill Of Processes Generator Organisation management Dataspace Connector Digital Twin (flow supported) Optimization Service (initial version available, not integrated) Predictive / Proactive Analytics (initial version available, not integrated) _____

User story ID	User story description	T4M Components
	After obtaining the estimated processing times, the Search & Match component automatically sends a request to retrieve the capacity data defined in the manufacturing resource digital twins deployed at the provider's site. This request is routed through the data space, involving both the T4M and Factory Level Data Space Connectors. **For the first validation iteration, the request for capacity information is not triggered, as dynamic data will only be incorporated in the final validation iteration. The workflow involving interactions between Organization Management ⇆ T4M Data Space Connector ⇆ Factory-Level Data Space Connector ⇆ Digital Twin—is already included US2.O3.** Finally, the process continues with a request to the Optimisation Service component to identify a set of candidate supply chain configurations that meet the selection criteria outlined in the MS Request. These configurations are subsequently evaluated and ranked through the Predictive / Proactive Analytics component. **For the first validation iteration, initial versions of both the Optimisation Service component and the Predictive/Proactive Analytics component, including the use of synthetic data, are available. The components are integrated in the pipeline but will use predefined static data as the dynamic data will only be available in the final validation iteration.**	Full workflow supported in the final validation iteration

Table 57: Validation: Initial iteration - VN2 Excluded user stories, use cases

User story ID	User story	T4M Components	Rationale
US2.P3	*"As the procurement representative I want a scoreboard of the proposed supply chain configurations along with a user interface that includes a selection feature, because I want to request service quotations from certain providers. "*	Supply Chain Monitoring (Negotiation and Agreement Visualization) Balanced Scorecard – Monitoring/ Reporting	Partially supported but not involved in current validation iteration. Included in final iteration.
US2.P4	*"As a sales representative I want a step-by-step offer wizard that allows for the review of the requests for services because I want to release service quotations "*	Supply Chain Monitoring (Negotiation and Agreement Visualization) Balanced Scorecard – Monitoring/ Reporting	Not supported in current validation iteration. Included in final iteration.
US2.P5	*"As a Consumer/Provider I want a facilitator for the exchange of information because I need to review, negotiate (with the Provider/Consumer) and release the selected manufacturing service order "*	Supply Chain Monitoring (Negotiation and Agreement Visualization)	Partially supported but not involved in current validation iteration. Included in final iteration.
US2.P6	*"As a Consumer/Provider I want a facilitator for the follow up of the released order because I need to monitor and tackle potential deviations from the original order agreement. "*	Supply Chain Monitoring (Negotiation and Agreement Visualization)	Partially supported but not involved in current validation

User story ID	User story	T4M Components	Rationale
			iteration. Included in final iteration.
US2.P7	*"As a procurement representative I want to be able to communicate with all members of the selected supply chain because I need to notify them for the validation of the service order. "*	Supply Chain Monitoring (Negotiation and Agreement Visualization)	Not supported in current validation iteration. Included in final iteration.
US2.P8	*"As Consumer/Provider I want a facilitator that enables access on a scoreboard because I need to provide an assessment of the performance of the Provider/Consumer. "*	Organisation management@	Not supported in current validation iteration Included in final iteration.

4.2.2 Validation KPIs

Given that this first validation iteration is based on early prototypes with limited features, the validation process focusses on a set Quality KPIs rather than full-scale operational metrics such as the Impact KPIs identified for the VN2 Pilot. Table 58 presents the functional, usability and performance related KPIs selected for the first iteration.

Table 58: Validation: Initial iteration - VN2 Selected KPIs

Concept	Selected KPIs	Acceptance criteria
Functional Suitability	Functional correctness rate (%)	>=98%
Usability	Number of usability issues (units)	<=3
	Perceived usability (qualitative in % + qualitative)	>=80 for quantitative values
	Number of critical defects	=0

4.2.3 Validation environment

Figure 18 provides a schematic view of the validation environment for the first iteration of the VN2 Pilot, including the T4M components involved in this initial validation iteration.

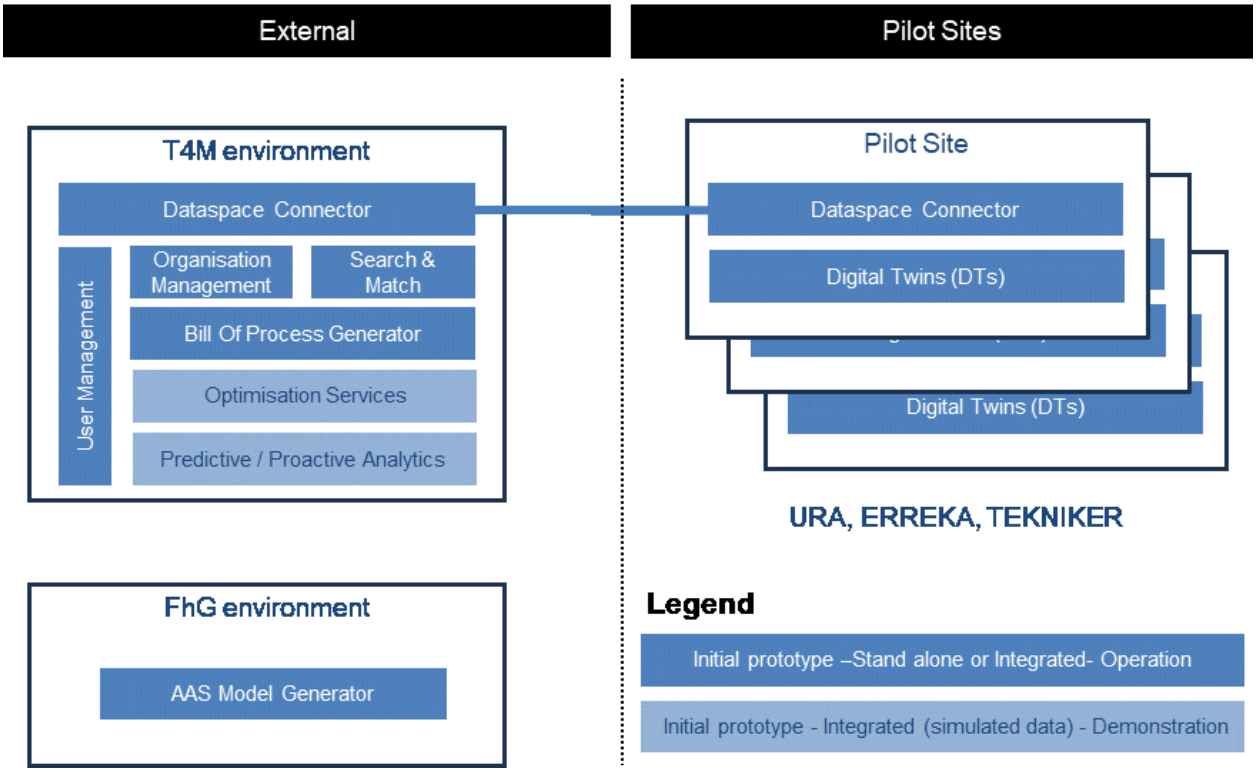

Figure 18: Validation: Initial iteration - VN2 Validation environnement

During the first validation iteration, the factory-level components (i.e., Digital Twins and Dataspace Connector) will be deployed and configured in the Pilot Sites involved in VN2 Pilot (i.e., URA, ERREKA, TEKNIKER).

4.2.4 Set-up validation

4.2.4.1 Site infrastructure preparation

The objective is to ensure infrastructure readiness of the Pilot Sites to proceed with the validation activities. Table 59 describes the system and software preconditions for the deployment of T4M components at Pilot Site level.

Table 59: Validation: Initial iteration - VN2 Systema and software requirements

T4M Component	System requirements	Software requirements
Digital Twin (DTs) FA³ST Service (AAS server)	Hardware requirements vary greatly depending on multiple aspects such as e.g. (i) size of the AAS model and additional files embedded in the model; (ii) number and type of asset connections; (iii) used implementations of the interfaces (e.g. using an embedded MQTT message bus requires more resources than the default internal message bus as it requires starting an MQTT broker inside FA³ST Service); (iv) number and type of endpoints, etc.	-

T4M Component	System requirements	Software requirements
Dataspace Connector (including AAS extension)	• **CPU**: 4 virtual CPUs (vCPUs) • **Memory**: 8 GB RAM • **Storage**: 50 GB disk space	FA³ST Service installed to access the AAS model.

Table 60 presents the preparation procedure to be followed by the Pilot Sites involved in VN2.

Table 60: Validation: Initial iteration - VN2 Pilot site preparation procedure

10	Description	Reference	Pilot sites	Responsible	Comment
1	Procurement and provisioning of the hardware infrastructure	-	URA	URA Pilot Site Coordinator	
			ERREKA	ERREKA Pilot Site Coordinator	
			TEKNIKER	TEKNIKER Pilot Site Coordinator	
2	Deployment of FA³ST Service (AAS Server) Dockerfile.	FA³ST.IM	URA	VN 2 Pilot Technical Partner (TEKNIKER)	
			ERREKA	ERREKA Pilot Site IT Representative VN 2 Pilot Technical Partner (TEKNIKER)	
			TEKNIKER	TEKNIKER Pilot Site IT Representative	
3	Configuration of FA³ST Service (AAS Server)	FA³ST .CM	URA	URA Pilot Site IT Representative VN 2 Pilot Technical Partner (TEKNIKER)	
			ERREKA	ERREKA Pilot Site IT Representative VN 2 Pilot Technical Partner (TEKNIKER)	
			TEKNIKER	TEKNIKER Pilot Site IT Representative	
4	Deployment and configuration of Dataspace Connector (including c AAS extension) Dockerfile.	DSC.IM	URA	URA Pilot Site IT Representative VN 2 Pilot Technical Partner (TEKNIKER)	
			ERREKA	ERREKA Pilot Site IT Representative VN 2 Pilot Technical Partner (TEKNIKER)	

10	Description	Reference	Pilot sites	Responsible	Comment
			TEKNIKER	TEKNIKER Pilot Site IT Representative	
5	Configuration of Dataspace Connector (including c AAS extension)	DSC.CM	URA	URA Pilot Site IT Representative VN 2 Pilot Technical Partner (TEKNIKER)	
			ERREKA	ERREKA Pilot Site IT Representative VN 2 Pilot Technical Partner (TEKNIKER)	
			TEKNIKER	TEKNIKER Pilot Site IT Representative	

4.2.4.2 Participants involvement

4.2.4.2.1 Participant Recruitment and Consent

Table 61 outlines the roles and target number of participants to be involved at each Value Network 2 Pilot Site for executing the validation activities detailed in the validation test cases. Participant roles were determined based on the relevant user stories, the T4M components included in the validation process, and the specific KPIs selected for measurement.

Table 61: Validation: Initial iteration - VN2 Participants

Role	Role description	Pilot Site	Quantity
Administration representative	Person acting on behalf of a company to register it into T4M. Registers the company with the selected role(s) with the appropriate.	URA	>=1
		ERREKA	>=1
		TEKNIKER	>=1
IT/Technical representative	Person with technical background supporting technical onboarding of providers, particularly in tasks like generating digital twins using the AAS Model Generator or data offering trough dataspace connector.	URA	>=1
		ERREKA	>=1
		TEKNIKER	>=2
Procurement representative	Person acting on behalf of a consumer company to request manufacturing services. URA and ERREKA request both AM and Machining services, and TEKNIKER requests Machining services.	URA	>=2
		ERREKA	>=2
		TEKNIKER	>=2
Additive Manufacturing Programmer	An expert in configuring and programming Computer Numerical Control (CNC) additive manufacturing (AMM) machines. Provides expert domain knowledge to validate the correctness of the outputs of the Bill of Processes Generator Plays also the role of Procurement responsible for AM services.	TEKNIKER	>=2
Machining Programmer	An expert in configuring and programming Computer Numerical Control (CNC) machines for subtractive manufacturing processes. Provides expert domain knowledge to validate the correctness of the outputs of the Bill of Processes Generator.	URA	>=2
		TEKNIKER	>=2

Role	Role description	Pilot Site	Quantity
	Plays also the role of Procurement responsible for Machining services.		

All the participants will receive an information sheet that clearly outlines the purpose, and the procedures involved in the validation process along with the informed consent form including withdrawal procedure T. he informed consent will be provided in both English and Spanish language.

Once participants have agreed to take part in the validation experiments, they will be invited to an initial presentation session. introducing the project's overall objectives, followed by a more detailed explanation of the specific goals of the upcoming experiment. Moreover, participants will receive a briefing on the issue management procedure, along with clear instructions on how to complete the issue reporting template and use the issue tracker effectively.

4.2.4.2.2 Participant Training

To ensure participants are adequately prepared, a series of training activities will be carried out prior to the start of the validation phase. The webinars will be recorded and made available for future reference. Table 62 identifies a set of webinars relevant to support the operation of VN2 Pilot

Table 62: Validation: Initial iteration - VN2 Training activities

Webinar	Objective	Responsible	T4M Components involved
Building AAS model with AAS model Generator	Explain how to generate an AAS model using the AAS Model Generator. Include example on how to create an AAS model with capabilities of a manufacturing resource.	IOSB	AAS model Generator
Defining Data Offering with Dataspace Connector	Explain how to define the data offering with the dataspace connector. Include examples on how to generate datasets from AAD model and associate usage policy.	TEKNIKER	Dataspace Connector
Getting started with T4M	Explain how to create users and register MaaS consumers and providers in T4M platform. Explain how to place a manufacturing request. Provide examples for additive manufacturing and machining services.	ATC	User Management Organization Management Search & Match

4.2.4.3 Ethical and legal compliance Ensure ethical and legal readiness

Table 63 identifies the personal data processed in the scope of the operation and validation activities for VN2 Pilot involving URA, ERREKA and TEKNIKER.

Table 63: Validation: Initial iteration - VN2 Processed personal data

Concept	Description
Identification Data	Participants will be identified using a unique code in the format ParticipantID (ID_Site_Number). Only the Pilot Site Coordinator will have access to personal identification details (such as name and institutional email address), strictly for coordination purposes. When referenced in results or documentation, participants will be identified only by their ParticipantID.
Health-Related Data	Not applicable — no health-related data will be collected.
Other Special Categories of Data	Not applicable — no sensitive personal data (e.g., racial or ethnic origin, political opinions, religious beliefs, etc.) will be processed.
Other Personal Data	Personal opinions related to usability may be collected during experimentation. Additionally, screen recordings are used, but without capturing voice or identifiable personal content. The usability interviews will not be recorded. In specific, consented cases, photos or interview recordings may be taken strictly for dissemination purposes, and only with prior explicit consent as outlined in the informed consent form signed by participants.
Location Data	No direct location data will be recorded. Only participants' institutional affiliation (e.g., organization or pilot site) will be collected.

Table 64describes how the collected personal data are being used and managed in the framework of VN2 Pilot.

Table 64: Validation: Initial iteration - VN2 Use and management personal data

Concept	Description
Personal data purpose,	Carry out the first validation iteration according to the validation plan and test cases and gather relevant feedback to support further improvements.
Personal data additional use	Photos or video recordings may be shared for dissemination purposes, as specified in the signed informed consent.
Personal data producer	Participants from URA, ERREKA and TEKNIKER) involved in the validation.
Personal data storage	Any personal data to be stores will include only the ParticipantID. Personal data already available a t Pilot Site level follows site internal rules fully compliant with privacy and data protection policies.
Personal data sharing	Photos or video recordings may be shared for dissemination purposes, as specified in the signed informed consent.
Data Controller (DC)	Pilot Site Data Controller. A specific DC is nominated for each pilot site (i.e., URA, ERREKA and TEKNIKER)
Data Processor (DP)	Person in charge of the analysis of the data collected during the experimentation to prepare the test case evaluation results.

4.2.4.4 Impact KPIs baseline

The first validation iteration does not include the measurement of impact KPIs or their baseline

4.2.5 Validation protocol

4.2.5.1 Test techniques

Table 65 introduces the test techniques foreseen in the first validation iteration.

Table 65: Validation: Initial iteration – VN2 Test techniques

Test technique name	Description
Workshop-Based Validation	Live, collaborative sessions where stakeholders observe system behavior with realistic data.
Functional Testing	Verifies that individual features or components work correctly with defined inputs and outputs.
Scenario-Based Testing	Tests end-to-end workflows based on real user stories to validate integration and overall system behavior across components.
Usability Testing:	Involves observing real users performing tasks to identify interface issues and evaluate user satisfaction and efficiency.

4.2.5.2 Validation test cases

This section defines the validation test cases designed to assess the functionality, usability, and performance of the T4M components included in the first validation iteration of the VN2 pilot.

The validations test cases identified for VN2 involve both common and VN specific use cases as summarised in the following table.

Table 66: Validation: Initial iteration – VN2 Validation tests cases summary

Validation test case	Description	User story Covered	Reference
TC.01.1	User and Role Management Functionality Validation	*US0.1*	Appendix C
TC.01.2	User Account Access and Management Validation	*US0.4*	Appendix C
TC.03.1	Consumer organization registration	US2.O1	Appendix C
TC.04.1	Provider organization registration	US2.O1, US2.O3	Appendix C
TC.05.1	Manual Search and Filtering of Manufacturing Service Providers	Extra functionality not initially identified	Appendix C
TC.06.1	Functional Validation and Data Flow: Optimisation Service to Post-Processing Analytics.	US2.P2	Appendix C
VN2.TC.01.1	Digital Twin Creation via AAS Model Generator	US2.O2	Section 4.2.5.2.1
VN2.TC.02.1	Data offering creation via Dataspace Connector (including AAS extension).	US2.O2	Section 4.2.5.2.1
VN2.TC.03.1	Request manufacturing service via Search & Match	US2.P1, US2.P2	Section 4.2.5.2.1

4.2.5.2.1 VN2 specific validation test cases

Find below the VN2 specific validation test cases.

Table 67: Validation: Initial iteration – VN2.TC.01.1

Concept	Description
Validation Test Case ID	VN2.TC.01.1
Test Title	Digital Twin Creation via AAS Model Generator
Test Techniques	Scenario-Based Testing
Related User Story	US2.O2
T4M Component	AAS Model Generator (i.e., FA³ST CreAItor)
Test Objective	Validate creation of AAS models including capability information for Additive Manufacturing/Machining resources. Assess the usability of GUI.
Preconditions	OpenAI API Key
Participant role/quantity	Domain experts from each Pilot Site in VN2.
Test Steps	1. Select the FA³ST CreAItor in the FA³ST Ecosystem. 2. Provide basic AAS Information manually or by uploading a CSV File. 2.1 Include a Name of the AAS Model. 2.2 Include an AAS ID. 2.3 Include Asset ID. 2.4 Click on “Create AAS and continue”. 3. Select Capability Description in the sidebar on the left. 4. Upload CSV File containing only information about one machine. 5. Click on “Add Capability SM to AAS 6. Download AAS in JSON or AASX format with the help of the sidebar 7. Open AAS Model in the AASX Package Explorer
Observation	• The System provides clear user messages if the actions are performed successfully • The System should not allow to continue if mandatory information is missing • The System should showcase the extracted Capability Description as JSON
KPIs	
KPI	**Number of critical defects**
Measurement method	Compare the generated results with the original input data in terms of • Correctness of extracted values • Completeness of extracted values • Invented values (Hallucinations)
Calculation method	• Correctness: Number of correct values in generated model/Number of actual values • Completeness: Number of values in generated model/Number of actual values • - Hallucinations: Number of invented values in the generated model
Success criteria	• Correctness > 90% • Completeness > 90%

Concept	Description
	• Hallucinations = 0
KPI	**Perceived usability**
Measurement method	Usability Experience questionnaire[7]
Calculation method	Using the standardized Useability Experience Questionnaire benchmark testing tool to determine Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty
Success criteria	A six useability criteria score Above Average in the benchmark test.

Table 68: Validation: Initial iteration – VN2.TC.02.1

Concept	Description
Validation Test Case ID	VN2.TC.02.1
Test Title	Data offering creation via Dataspace Connector (including AAS extension).
Test Techniques	Scenario-Based Testing, Usability Testing
Related User Story	US2.O2
T4M Component	Dataspace Connector (including AAS extension)
Test Objective	Validate creation of data offering, based on an AAS model. Assess the usability of the GUI of the Dataspace Connector.
Preconditions	AAS model available and deployed in FA³ST. Endpoint of the FA3ST server configured
Participant role/quantity	IT/Technical representative from each Pilot Site in VN2.
Test Steps	1. Describe the Catalog by providing title, keywords, descriptions 2. Select the AAS model. 3. Request the creation of the datasets. 4. Access the Dataspace Connector UI and verify the Datasets have been created in the Catalog 5. Test the link for Datasets and check a JSON file is made available. 6. Use the filtering options. 7. Select a dataset and identify the datasets that are related to it.
Observation	-
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0
KPI	**Number of usability issues (units)**

[7] User Experience Questionnaire (UEQ)

Concept	Description
Measurement method	Screen video recording
Calculation method	Observe video recording and identify usability issues when performed the identified test steps.
Success criteria	Number of usability issues<3
KPI	**Perceived usability**
Measurement method	Usability questionnaire based on SUS questionnaire.
Calculation method	The evaluation method proposed by SUS – For quantitative values.
Success criteria	>=80

Table 69: Validation: Initial iteration – VN2.TC.03.1

Concept	Description
Validation Test Case ID	VN2.TC.03.1
Test Title	Request manufacturing service via Search & Match
Test Techniques	Scenario-Based Testing, Functional Testing, Usability Testing
Related User Story	US2.P1, US2.P2
T4M Component	Search & Match, Bill of Processes Generator, Organization management
Test Objective	Validate submission of Manufacturing Service Request and assess GUI usability. Assess the functional correctness of the Bill of Processes Generator. Functional Validation, Form Validation, UI Workflow Validation, Data Integrity Validation
Preconditions	• Consumer organization registered. • User login. • All system services related to service requests are operational.
Participant role/quantity	Procurement representative, Machining Programmer, Additive Manufacturing Programmer from the Pilot Sites in VN2.
Test Steps	1. Participant Logs in 2. Participant access manufacturing request option 3. Participant selects service type (AM or Machining) 4. Participant enters the requested information depending on the selected type. 5. Participant submits request.
Observation	The process should be repeated for at least 15 requests for Additive Manufacturing Services (at least 50% of them including finishing services) and at least 20 requests for Machining services. The requests should involve a representative set of parts and materials.
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.

Concept	Description
Success criteria	Number of critical defects=0
KPI	**Number of usability issues (units)**
Measurement method	Screen video recording
Calculation method	Observe video recording and identify usability issues when performed the identified test steps.
Success criteria	Number of usability issues<3
KPI	Perceived usability
Measurement method	Screen video recording
Calculation method	Observe video recording and identify usability issues when performed the identified test steps.
Success criteria	Number of usability issues<3
KPI	**Functional correctness rate (%) of Bill of Processes Generator**
Measurement method	System logs.
Calculation method	Additive Manufacturing and/or Machining Programmer should complete a template with the expected outputs based on their previous knowledge. The expected outputs declared by the domain experts are compared with the obtained outputs from the Bill of Processes Generator by comparing them with the obtained logs. The ratio is calculated by using the formula described in section 2.5.
Success criteria	Functional correctness rate BoP (%)>=98%

4.2.5.3 Test completion and retesting criteria

4.2.5.3.1 Test completion criteria

In the first validation iteration, test completion is achieved once all planned test cases for the limited set of features and user stories are executed. Emphasis is placed on verifying the core functionalities critical to this early prototype phase, ensuring they meet predefined acceptance criteria without any unresolved critical defects. Throughout testing, detailed documentation captures the results of each case, including any failures or blockers encountered. Issues are managed following T4M issue management procedure.

4.2.5.3.2 Retesting criteria

Retesting is carried out primarily to verify fixes for identified defects and to confirm that changes have not adversely affected existing functionality. When defects are resolved, associated test cases are re-executed. any tests previously blocked by environmental or dependency issues are completed once conditions allow. Additionally, if any significant improvement related to the defined test cases is deployed during the validation iteration the associated test cases should be re-executed.

4.2.6 Risk management

The Risk Management phase aims to ensure that potential issues that could compromise the success, safety, or accuracy of the validation process are identified, assessed, and proactively managed.

Table 37 presents the key risks identified and the mitigation activities put in place.

Table 70: Validation: Initial iteration - VN2 Risk management

Risk Id	Risk Description	L	I	E	Mitigation activity
VN2.1.R1	Low availability or engagement of pilot users	2	4	8	Involve participant early and provide information on the purpose of the validation as well as training sessions. See sections 4.2.4.2.1 and 4.2.4.2.2
VN2.1.R2	Failure to meet minimum number of test participants	2	4	8	Identify and commit participants early; have backup users identified.
VN2.1.R3	Misunderstanding of validation objectives or procedures by participants	2	3	6	Include goals and procedures overview in presentation and training sessions. See section 4.2.4.2.1.
VN2.1.R4	Participants are not sufficiently trained to use the components being validated	3	4	12	Conduct training webinars and share recorded sessions for later review. See section 4.2.4.2.2
VN2.1.R5	Validation timeline not aligned with availability of key staff	3	4	12	Create detailed timeline as part of the validation plan and confirm availability with stakeholders. See section 4.2.7.
VN2.1.R6	Inaccurate or incomplete logging of issues during validation	2	3	6	Brief all participants on usage of the issue reporting template and issue tracker prior to start the validation phase. See section 4.2.4.2.1.
VN2.1.R7	Incomplete or unclear validation plans at VN Pilot and Pilot site level.	3	3	9	Provide a structured validation protocol. See section 4.2.5
VN2.1.R8	Data collection issues during validation activities	3	3	9	Define data formats/tools early and appoint responsible persons as part of the test case definition in the validation plan. See section 4.2.5.2validation

4.2.7 Schedule timeline and milestones

This section presents the timeline and key milestones for the initial validation iteration of the VN2 pilot, which focuses on validating the T4M platform in the context of distributed manufacturing services involving plastic injection moulding, additive manufacturing, and machining. The objective is to provide a structured and time-bound roadmap for executing the validation activities. Table 37 presents the validation schedule for the first iteration.

Table 71: Validation: Initial iteration – VN2 Validation schedule

Phase	Activity Description	Start Date	End Dat	Milestone / Deliverable	Responsible	Remarks / Dependencies
Preparation	Finalization of validation plan and test case definitions	May 2025	June 2025	Internal validation plan approved	TEKNIKER, URA, ERREKA	Validation strategy and Validation Preparation

Phase	Activity Description	Start Date	End Dat	Milestone / Deliverable	Responsible	Remarks / Dependencies
						Methodology ready
Environment Setup	Deployment of pilot environment at TEKNIKER	June 2025	June 2025	TEKNIKER pilot site operational	TEKNIKER	Enables early testing of T4M components and potential problems during deployment a
Environment Setup	Deployment of pilot environments at URA and ERREKA	July 2025	August 2025	URA and ERREKA pilot sites operational	URA, ERREKA	Lessons from TEKNIKER deployment to be applied
Training & Onboarding	Training sessions for participants on T4M tools and validation procedures	July 2025	Sept 2025	Training completed	TEKNIKER, Component Owners	Webinars recorded and shared for reuse
Validation Execution	Execution of test cases at TEKNIKER	July 2025	Nov 2025	Test results collected	TEKNIKER	First iteration validation plan ready
Validation Execution	Execution of test cases at URA and ERREKA	Sept 2025	Nov 2025	Test results collected	URA, ERREKA	First iteration validation plan ready
Analysis & Reporting	Consolidation and analysis of validation results	Nov 2025	Dec 2025	Input to D5.2 – Pilots Execution and Evaluation v1	TEKNIKER, URA, ERREKA	Requires complete data from all pilot sites

The deployment of the pilot environment is intentionally phased, beginning with TEKNIKER followed by URA and ERREKA. This sequencing is strategic and since TEKNIKER, as both a technical partner and a pilot site. By deploying first at TEKNIKER, the project team can identify and resolve potential deployment or integration issues before rolling out to the other pilot sites. This approach ensures that the environments at URA and ERREKA benefit from a more mature and stable setup. Moreover, TEKNIKER's experience serves as a reference point, providing practical guidance that support the successful deployment and operation of the platform at the other sites.

4.3 VN3 validation plan

4.3.1 Purpose and scope

4.3.1.1 Validation purpose

The purpose of the validation of the Information Modelling Framework (IMF) in VN3 is to verify that IMF, as applied in the VN3, can effectively capture the data content for the data exchange between AIBEL and its supplier Endress+Hauser for the task of specifying the requirements to and specification of technical equipment, and that it can reflect the incremental detailing of information that takes place in this process. It is important to note that IMF is considered less of a traditional software "component" and more of a language and methodology for representing information, following principles for systems engineering and information modelling. The technology used in the verification are open-source implementations that support the open W3C standards such as RDF, SHACL and OWL, that IMF uses.

The purpose of validation in the case of the Supply Chain Monitoring (SMC) on the other hand, is to verify through the VN3 test case the effective performance of the tool in the main tasks involved in the Tec4MaaSEs ecosystem, including collaboration establishment, negotiations on the specifics or a manufacturing service, and order arrangement and monitoring.

Table 72: Validation: Initial iteration - VN3 Internal References

Code	Document	Description	Comments
D2.1	Reference cases and actionable models for reconfigurable value networks and service decomposition v1	Describes Value Network 3 use case stories and related use cases-	Initial version
D2.5	Tech4MaaSEs architecture blueprint and specifications v1	Outlines T4M components and their interactions in Value Network 3 via sequence diagrams	Initial version

Table 73: Validation: Initial iteration- VN3 External References

Code	Document	Description	Comments
IMF	Information Modelling Framework Manual v0.3.0	Introduces IMF and explains how IMF can be used for engineering facility asset.	Access link

4.3.1.2 Validation scope

The figure below shows the complete user story between VN3 Pilots and its supplier. The current validation iteration focuses on the information exchange in the inquiry and partly bid clarification stages. This section lists the user stories that are partially or fully addressed in the current validation iteration and outlines those that are excluded.

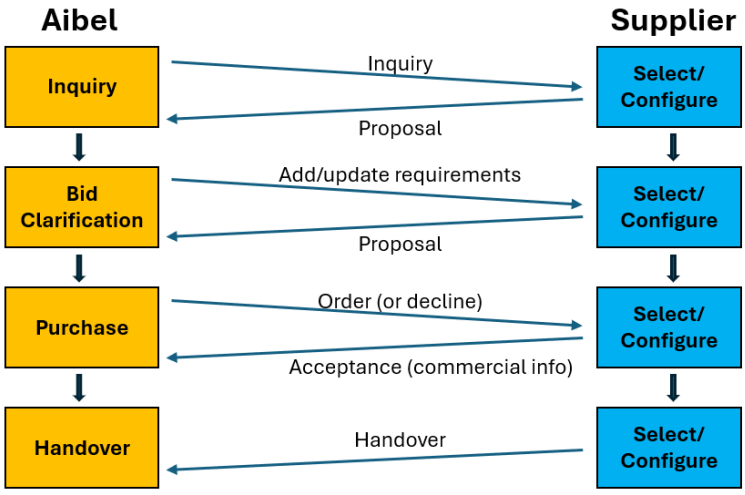

Figure 19: Validation: Initial iteration - VN3 Exchange of information process between purchaser and supplier

Table 74: Validation: Initial iteration – VN3 Included user stories, use cases

User story ID	User story description	T4M Components
US0.1	*"As a Super-User, I want to create, update, and delete user roles and user accounts through the User Interface, so that I can manage access permissions and maintain up-to-date user data within the Tec4MaaSEs system."*	User management
US0.4	*"As a user, I want to activate my account, log in, update my account details, and log out via the Tec4MaaSEs User Interface, so that I can securely access and manage my account within the platform. This applies to both MaaS consumers and MaaS providers."* T4M's users manage their accounts through a secure process that includes activation, login, profile updates, and logout. Users activate their accounts via an email link, setting a password through the UI, which is verified by the User Management component. After activation, users log in with their credentials, receiving access and refresh tokens upon successful authentication. They can update account details via the UI, with changes verified and applied by User Management. Logging out ends the session securely, with the UI redirecting the user appropriately. This flow ensures secure and user-friendly access management on the platform. **For the first validation iteration initial version of the core functionalities such as account activation, log in, update account details, and log out are available however organization the verifiable credentials are not yet considered.**	User management
US3.1	*"As a Consumer / Provider I want to register my organization to the T4M platform to enable Manufacturing as a Service procurement of equipment packages."*	Organisation Management
US3.3	*"As a Consumer PRB or Provider PRE, I want a step-by-step wizard that enables me to create a new asset (e.g. Information Model) by providing information from my engineering systems so that I can upload it to T4M or utilize an already existing asset I was given access to in order to enable a consumer-provider interaction through Information models"*	Semantic Framework, IMF Editor

User story ID	User story description	T4M Components
	For the first validation iteration, the IMF Editor will be used to capture engineering information in as information models which can be exported as DTs in AAS format and consumed by T4M.	
US3.4	*"As a Consumer PRB I want to issue a new Enquiry for equipment packages to selected providers and receive Offers through Information Models in order to be able to have optimized use of time and avoid errors in the information exchange."* **For the first validation iteration, enquires for equipment packages will be represented as functional and design requirements in the form of information models, that can be issued to T4M as DTs in AAS format. A subset of their characteristics (capabilities, properties corresponding to capacities) can be consumed by Supply Chain Monitoring component to generate DTs with these characteristics. Conversations between collaborators in the Supply Chain Monitoring component can support the exchange of files, and an environment to send and receive orders.**	Semantic Framework, Supply Chain Monitoring
US3.5	*"As a Consumer PRB I want to issue a Purchase Order and track its evolution until the completion of the facility development in order to monitor all interactions and updates in the process"* **For the first validation iteration, the engineering information that is accompanied by a purchase order will be represented as an information models that will be issued to T4M in as DTs in AAS format. The order details and negotiations can be handled within Supply Chain Monitoring component conversations.**	Semantic Framework, Supply Chain Monitoring
US3.6	*As a Consumer PRB/PRE – Provider PRE want to interact (question, answer, annotate, etc.) on Information Models to be able to save time and avoid errors* **For the first validation iteration, the information models will be represented in the form of RDF knowledge graphs which supports SPARQL query answering. The IMF model and the RDF knowledge graph can be annotated using standard annotation vocabularies.**	Semantic Framework
US3.7	*As a Consumer PRB/PRE – Provider PRE want to Initiate a Change Control Process to evaluate an identified needed change in the equipment packages.* **For the first validation iteration, this use case is only supported partially. Supply Chain Monitoring component conversations offer custom templates, where users can define a structured form with strongly typed fields. Using a common ontology and a mutually agreed structure, some simple cases can be supported in terms of communicating the necessary changes in an unambiguous way and then discussing on them and monitoring the progress of the process.**	Supply Chain Monitoring (Partially)

Table 75: Validation: Initial iteration – VN3 Excluded user stories

User story ID	User story	T4M Components	Rationale
US3.2	*"As the Consumer PRB I want to Grant / Revoke Access to the Consumer PRE and Providers' PREs in order to enable them to view and interact with the various Information Models."*	The Semantic Framework is not integrated, and the platform will not directly consume information models in the first iteration.	The Semantic Framework is not integrated, and the platform will not directly consume

User story ID	User story	T4M Components	Rationale
			information models in the first iteration.

4.3.2 Validation KPIs

As this first VN3 validation iteration focuses on applying and refining models for the AIBEL use case using IMF, semantic technologies, and AAS. The validation process focusses on a set Quality KPIs rather than full-scale operational metrics such as the Impact KPIs identified for the VN3 Pilot. Table presents the functional, usability and performance related KPIs selected for the first iteration.

Table 76: Validation: Initial iteration – VN3 Selected KPIs

Concept	Selected KPIs	Acceptance criteria
Functional Suitability	Functional correctness rate (%)	>=95%
Usability	Number of usability issues (units)	<=3
	Perceived usability (qualitative in % + qualitative)	>=70 for quantitative values
Performance	Response time (seconds)	< 10
	Number of critical defects	= 0

4.3.3 Validation environment

No complex factory-level deployment is envisioned for this validation iteration, unlike VN1/VN2, as the focus is on information modelling and semantic validation. The Supply Chain Monitoring is implemented on a single up and running instance of the Supply Chain Monitoring component, already deployed well in advance.

4.3.4 Set-up validation

4.3.4.1 Site infrastructure preparation

The objective is to ensure infrastructure readiness of the Pilot Sites to proceed with the validation activities.

Table 77: Validation: Initial iteration – VN3 Systema and software requirements

T4M Component	System requirements	Software requirements
IMF Editor	None – Desktop application	
Semantic framework	None – Desktop applications	Semantic technology tool support (RDF, SHACL, OWL). Many open-source options available.
Supply Chain Monitoring	None - Standalone Deployment	Supply Chain Monitoring component features on Negotiations, Conversations and Order Specifications

4.3.4.2 Participants involvement

4.3.4.2.1 Participant Recruitment and Consent

Table 78 outlines the roles and target number of participants to be involved at each Value Network 3 Pilot Site. Participant roles were determined based on the relevant user stories, the T4M components included in the validation process, and the specific KPIs selected for measurement.

Table 78: Validation: Initial iteration - VN3 Participants

Role	Role description	Pilot Site	Quantity
Administration representative	Person acting on behalf of a company to register it into T4M. Registers the company with the selected role(s) with the appropriate.	AIBEL	>=1
IT/Technical representative	Person with technical background supporting technical onboarding of providers, particularly in tasks like generating information model and AAS.	AIBEL	>=2
		UiO	
Procurement representative	Person acting on behalf of a consumer company to request manufacturing services.	AIBEL	>=2

4.3.4.2.2 Participant Training

To ensure participants are adequately prepared, a series of training activities will be carried out prior to the start of the validation phase. The webinars will be recorded and made available for future reference. Table 79 identifies a set of webinars relevant to support the operation of VN3 Pilot.

Table 79: Validation: Initial iteration – VN3 Training activities

Webinar	Objective	Responsible	T4M Components involved
Building IMF models	Explain how to build an IMF model using the IMF Editor. Include example on how to build an IMF model to model systems engineering's break-down in UFD and P&ID.	UiO	IMF Editor
Validating IMF models	Explain how to translate graphical IMF models to RDF knowledge graphs and perform validation of such graphs using semantic technologies such as SHACL and OWL.	UiO	Semantic Framework, IMF Editor
Getting started with T4M	Explain how to create users and register organizations as providers or consumers in T4M platform. Provide examples for the registration process.	ATC	User Management, Organization Management
Manual Search	Explain how to search manually for providers with specific criteria. Provide examples for different types of criteria.	ATC	Organization Management

Webinar	Objective	Responsible	T4M Components involved
Handling Negotiations & Collaborator Interactions with Supply Chain Monitoring component	Explain the infrastructure, user roles, systemic entities and collaboration environments to pilot representative, in order to ensure they can fully implement user stories demanding interactions between Supply Chain Monitoring component organisations.	MAG	Supply Chain Monitoring

4.3.4.3 Ethical and legal compliance Ensure ethical and legal readiness

Table 80 identifies the personal data processed in the scope of the operation and validation activities for VN3 Pilot.

Table 80: Validation: Initial iteration - VN3 Processed personal data

Concept	Description
Identification Data	Participants will be identified using a unique code in the format ParticipantID (ID_Site_Number). Only the Pilot Site Coordinator will have access to personal identification details (such as name and institutional email address), strictly for coordination purposes. When referenced in results or documentation, participants will be identified only by their ParticipantID.
Health-Related Data	Not applicable — no health-related data will be collected.
Other Special Categories of Data	Not applicable — no sensitive personal data (e.g., racial or ethnic origin, political opinions, religious beliefs, etc.) will be processed.
Other Personal Data	Not applicable — no sensitive personal data (e.g., racial or ethnic origin, political opinions, religious beliefs, etc.) will be processed.
Location Data	No direct location data will be recorded. Only participants' institutional affiliation (e.g., organization or pilot site) will be collected.

Table 81 describe how the collected personal data are being used and managed in the framework of VN3 Pilot.

Table 81: Validation: Initial iteration - VN3 Use and management personal data

Concept	Description
Personal data purpose,	Carry out the first validation iteration according to the validation plan and test cases and gather relevant feedback to support further improvements.
Personal data additional use	Photos or video recordings may be shared for dissemination purposes, as specified in the signed informed consent.
Personal data producer	Participants from AIBEL, UiO and MAG involved in the validation.
Personal data storage	Any personal data to be stores will include only the ParticipantID. Personal data already available a t Pilot Site level follows site internal rules fully compliant with privacy and data protection policies.

Concept	Description
Personal data sharing	Photos or video recordings may be shared for dissemination purposes, as specified in the signed informed consent.
Data Controller (DC)	Pilot Site Data Controller. A specific DC is nominated for each pilot site (i.e., AIBEL, UiO and MAG)
Data Processor (DP)	Person in charge of the analysis of the data collected during the experimentation to prepare the test case evaluation results.

4.3.4.4 Impact KPIs baseline

The first validation iteration does not include the measurement of impact KPIs or their baseline.

4.3.5 Validation protocol

4.3.5.1 Test techniques

Table 82 introduces the test techniques foreseen in the first validation iteration.

Table 82: Validation: Initial iteration – VN3 Pilot - Test techniques-

Test technique name	Description
Workshop-Based Validation	Live, collaborative sessions where stakeholders observe system behaviour with realistic data.
Functional Testing	Verifies that individual features or components work correctly with defined inputs and outputs.
Scenario-Based Testing	Tests end-to-end workflows based on real user stories to validate integration and overall system behaviour across components.
Usability Testing:	Involves observing real users performing tasks to identify interface issues and evaluate user satisfaction and efficiency.

4.3.5.2 Validation test cases

This section defines the validation test cases designed to assess the functionality, usability, and performance of the T4M components included in the first validation iteration of the VN3 pilot.

The validations test cases identified for VN3 involve both common and VN specific use cases as summarised in the following table.

Table 83: Validation: Initial iteration – VN3 Validation tests cases summary

Validation test case	Description	User story Covered	Reference
TC.01.1	User and Role Management Functionality Validation	*US0.1*	Appendix C
TC.01.2	User Account Access and Management Validation	*US0.4*	Appendix C
TC.03.1	Consumer organization registration	US3.1	Appendix C
TC.04.1	Provider organization registration	US3.1	Appendix C
TC.05.1	Manual Search and Filtering of Manufacturing Service Providers	US3.4	Appendix C

Validation test case	Description	User story Covered	Reference
TC.06.1	Functional Validation and Data Flow: Optimisation Service to Post-Processing Analytics.	US2.P2	Appendix C
VN3.TC.01.1	IMF Modelling of AIBEL "Ping-Pong" Use Case – workshop-based validation	US3.3, US3.4, US3.5	Section 4.3.5.2.1
VN3.TC.02.1	Issuing an Enquiry AAS with Functional/Design Requirements	US3.4	Section 4.3.5.2.1
VN3.TC.03.1	Issuing a Purchase Order accompanied with AAS that contains engineering information	US3.5	Section 4.3.5.2.1
VN3.TC.04.1	IMF model requirements—solution validation	US3.4	Section 4.3.5.2.1
VN3.TC.05.1	IMF model query answering	US3.6	Section 4.3.5.2.1

4.3.5.2.1 VN3 specific validation test cases

Find below the VN3 specific validation test cases.

Table 84: Validation: Initial iteration – VN3.TC.01.1

Concept	Description
Validation Test Case ID	VN3.TC.01.1
Test Title	IMF Modelling of AIBEL "Ping-Pong" Use Case – workshop-based validation
Test Techniques	Workshop-Based Validation
Related User Story	US3.3, US3.4, US3.5
T4M Component	Semantic Framework (IMF), IMF Editor, Supply Chain Monitoring (SCM)
Test Objective	Validate IMF's ability to model incremental detailing of information, requirements, specifications, and the "ping-pong" exchange for the AIBEL use case (e.g., flow pressure transmitter).
Preconditions	Sufficient information and data to represent the information in the exchange.
Participant role/quantity	Information modeler, subject matter expert (domain engineering expert)
Test Steps	1. Define modelling requirements and scope, identify information sources 2. Build IMF model using IMF Editor and IMF modelling guidelines. 3. Validate IMF model using validation tools 4. Manually verify IMF model correctness 5. Exchange the model using Supply Chain Monitoring component conversations and re-iterate until requirements are captured.
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0

Concept	Description
KPI	**Number of usability issues (units)**
Measurement method	Manual observation
Calculation method	Identify usability issues when performed the identified test steps.
Success criteria	Number of usability issues <3
KPI	**Perceived usability**
Measurement method	Usability questionnaire based on SUS questionnaire.
Calculation method	The evaluation method proposed by SUS – for quantitative values.
Success criteria	>=70

Table 85: Validation: Initial iteration – VN3.TC.02.1

Concept	Description
Validation Test Case ID	VN3.TC.02.1
Test Title	Issuing an Enquiry AAS with Functional/Design Requirements
Test Techniques	Scenario-Based Testing, Functional Testing
Related User Story	US3.4
T4M Component	Digital Twin – Semantic Framework (IMF)
Test Objective	To validate that a user can define an enquiry using functional and design requirements, and that the system correctly packages these requirements into an AAS with correct Submodel (as a Digital Twin) via IMF model
Preconditions	IMF model for functional and design requirements is defined/built Tool/script to translate IMF to specific AAS Submodel.
Participant role/quantity	Information modeler, subject matter expert (domain engineering expert)
Test Steps	1. Select the built IMF model for functional and design requirements 2. Use predefined tool to translate IMF model into AAS with Submodel in JSON or AASX format 3. Open AAS model with AASX Package Explorer 4. Manually verify the correctness and completeness of the values in generated AAS model
Observation	1.The tool translate IMF to AAS correctly and follow the AAS Submodel template structure 2.The generated AAS should be correctly opened by AAS Package Explorer
KPIs	
KPI	**Number of critical defects**
Measurement method	Compare the generated results with the original information in the model in two ways: Completeness of the generated results Correctness of the generated results
Calculation method	Manual calculation for missing values and incorrect values
Success criteria	Number of critical defects=0

Concept	Description
KPI	**Number of usability issues (units)**
Measurement method	Manual observation
Calculation method	Identify usability issues when tester encounter difficulty to continue the test case.
Success criteria	Number of usability issues <3
KPI	**Perceived usability**
Measurement method	Usability questionnaire based on SUS questionnaire.
Calculation method	The evaluation method proposed by SUS – for quantitative values.
Success criteria	>=70

Table 86: Validation: Initial iteration – VN3.TC.03.1

Concept	Description
Validation Test Case ID	VN3.TC.03.1
Test Title	Issuing a Purchase Order accompanied with AAS that contains engineering information
Test Techniques	Scenario-Based Testing, Functional Testing
Related User Story	US3.5
T4M Component	Digital Twin – Semantic Framework (IMF), Supply Chain Monitoring (SCM)
Test Objective	To validate that a user can use IMF model to generate an AAS model that contains sufficient engineering information to accompany the purchase order
Preconditions	Engineering information IMF model for purchase order is defined/built Tool/script to translate IMF to specific AAS Submodel.
Participant role/quantity	Information modeler, subject matter expert (domain engineering expert)
Test Steps	1. Select the built IMF model for purchase order engineering information 2. Use predefined tool to translate IMF model into AAS with Submodel in JSON or AASX format 3. Open AAS model with AASX Package Explorer 4. Manually verify the correctness and completeness of the generated AAS model 5. Manually check the IRIs (Internationalized Resource Identifier) in the IMF model are correctly added as semantic IDs to the generated engineering information in AAS. 6. Initiate a conversation in Supply Chain Monitoring component to send the order, by attaching the model file. An order form template can be used to handle standardised fields.
Observation	1.The tool translate IMF to AAS correctly and follow the AAS Submodel template structure 2.The generated AAS should be correctly opened by AAS Package Explorer 3. The IRIs should be correctly added to the generated information in AAs
KPIs	
KPI	**Number of critical defects**
Measurement method	Compare the generated results in AAS with the original information in the model in two ways:

Concept	Description
	• Completeness of the generated information • Correctness of the generated information • Completeness of the added IRIs • Correctness of the added IRIs
Calculation method	Manual calculation for missing values and incorrect values
Success criteria	Number of critical defects=0
KPI	**Number of usability issues (units)**
Measurement method	Manual observation
Calculation method	Identify usability issues when tester encounter difficulty to continue the test case.
Success criteria	Number of usability issues <3
KPI	**Perceived usability**
Measurement method	Usability questionnaire based on SUS questionnaire.
Calculation method	The evaluation method proposed by SUS – for quantitative values.
Success criteria	>=70

Table 87: Validation: Initial iteration – VN3.TC.04.1

Concept	Description
Validation Test Case ID	VN3.TC.04.1
Test Title	IMF model requirements—solution validation
Test Techniques	Scenario-Based Testing, Functional Testing
Related User Story	US3.4
T4M Component	IMF Editor, Semantic Framework (IMF)
Test Objective	Demonstrate validation of technical product specification against functional requirements using the IMF and standard semantic technologies.
Preconditions	IMF model representing functional requirements and product specification(s).
Participant role/quantity	Information modeler
Test Steps	1. Export IMF model to RDF knowledge graph (KG) format using IMF Editor export functionality 2. Validate KG against IMF OWL and SHACL specification using open-source semantic technology tool suite 3. Translate KG to OWL ontology format using Semantic Framework 4. Validate using the OWL ontology and open-source reasoning tools that product specification(s) meet functional requirements
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.

Concept	Description
Success criteria	Number of critical defects=0

Table 88: Validation: Initial iteration – VN3.TC.05.1

Concept	Description
Validation Test Case ID	VN3.TC.05.1
Test Title	IMF model query answering
Test Techniques	Scenario-Based Testing, Functional Testing
Related User Story	US3.6
T4M Component	IMF Editor, Semantic Framework (IMF)
Test Objective	Demonstrate that information models can be used to answer questions through formal queries over a knowledge graph representation of the information model.
Preconditions	IMF model representing technical information.
Participant role/quantity	Information modeler
Test Steps	1. Export IMF model to RDF knowledge graph (KG) format using IMF Editor export functionality 2. Load KG into open-source graph database supporting RDF and SPARQL queries. 3. Formulate user questions as SPARQL queries. 4. Execute SPARQL queries on KG in database
Observation	
KPIs	
KPI	Number of critical defects
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0

4.3.5.3 Test completion and retesting criteria

4.3.5.3.1 Test completion criteria

For the first round of validation, we will run all planned tests on a core set of features. The main goal is to check that these key functions meet their requirements and have no critical bugs. We will keep detailed records of all test results. Any issues discovered will be handled using the T4M management procedure.

4.3.5.3.2 Retesting criteria

Retesting focuses on two key goals: verifying that bug fixes work correctly and confirming that these changes haven't created new problems (regression testing). Once a defect is resolved, we re-run the associated test case. This phase also includes completing any tests that were previously blocked by environmental or dependency issues.

4.3.6 Risk management

Table 89 summarizes the key risks identified for the first iteration validation of VN2 pilot and outlines the corresponding mitigation strategies to ensure smooth execution of the initial validation iteration.

Table 89: Validation: Initial iteration – VN3Risk management

Risk Id	Risk Description	L	I	E	Mitigation activity
VN3.1.R.1	Delay or insufficient detail in AIBEL providing necessary input data, documentation (use case, diagrams, AAS models, zone breakdown, reference data IDs).	3	4	12	Regular communication with AIBEL, clearly define data needs in advance, agree on delivery timelines. Use placeholder/example data if delays occur to keep modeling work progressing.
VN3.1.R.2	Complexity in accurately modelling the "ping-pong" exchange and incremental detailing within IMF proves higher than anticipated, leading to delays or overly complex models.	3	3	9	Start with simplified exchange scenarios, iterate on model complexity based on feedback. Focus on core information exchange first. Regular reviews with AIBEL.
VN3.1.R.3	Difficulties in implementing or demonstrating impactful semantic technology use cases due to tool limitations, complexity of rule definition, or unavailability of suitable reference data.	3	3	9	Prioritize simple, high-impact semantic use cases. Start with readily available tools and reference data. Develop detailed use case descriptions for semantic tech applications early.
VN3.1.R.4	Issues with AAS submodel compatibility, bugs in existing AAS models/tools, or challenges in updating AAS models to latest versions/templates.	2	3	6	Use official/validated AAS tools where possible. Address known bugs proactively with domain engineers and AAS experts. Allocate time for troubleshooting AAS updates.

4.3.7 Schedule timeline and milestones

Table 90: Validation: Initial iteration – VN3 Validation schedule

Phase	Activity Description	Start Date	End Dat	Milestone / Deliverable	Responsible	Remarks / Dependencies
Preparation	Finalization of validation plan and test case definitions	May 2025	June 2025	Internal validation plan approved	MAG, UiO, AIBEL	Validation strategy and Validation Preparation Methodology ready
Environment Setup	Deployment of T4M environment in Supply Chain Monitoring	June 2025	June 2025	Operational systems	MAG, UiO	Enables early testing of T4M components and potential problems during deployment

Phase	Activity Description	Start Date	End Dat	Milestone / Deliverable	Responsible	Remarks / Dependencies
	component and IMF					
Training & Onboarding	Training sessions for participants on T4M tools and validation procedures	July 2025	Sept 2025	Training completed	MAG, UiO, AIBEL	None
Validation Execution	Execution of test cases	July 2025	Nov 2025	Test results collected	MAG, UiO	First iteration validation plan ready
Validation Execution	Execution of test cases at AIBEL	Sept 2025	Nov 2025	Test results collected	MAG, UiO, AIBEL	First iteration validation plan ready
Analysis & Reporting	Consolidation and analysis of validation results	Nov 2025	Dec 2025	Input to D5.2 – Pilots Execution and Evaluation v1	MAG, UiO, AIBEL	Requires complete data from all pilot sites

Conclusions

Deliverable D5.1 establishes the foundation for the validation of the Tec4MaaSEs (T4M) platform through a structured, iterative, and stakeholder-driven approach. It defines the overall validation strategy, preparation methodology, and detailed plans for the initial validation iteration across the three Value Networks (VN1, VN2, and VN3). These pilots represent diverse industrial contexts and serve as real-world environments to assess the performance, usability, and impact of the T4M solution.

The document introduces a comprehensive validation methodology that integrates best practices from international standards, emphasizes early and continuous user involvement, and ensures ethical and legal compliance. It outlines the selection of Key Performance Indicators (KPIs), the setup of validation environments, and the development of detailed test cases tailored to each pilot's specific use cases and technological components. A proactive risk management strategy and a structured validation schedule have been defined to ensure smooth execution and timely delivery of results. The initial validation iteration focuses on testing early prototypes and core functionalities, while subsequent phases will progressively integrate and validate additional features, culminating in a final validation iteration that assesses the complete T4M solution in operational settings. Each Value Network has developed a tailored validation plan, supported by a robust assessment framework that combines both impact and quality KPIs. These plans ensure that the validation process is aligned with the strategic goals of the project and the operational needs of the industrial partners. Finally, the deliverable includes a detailed issue management strategy to ensure that any problems encountered during validation are systematically tracked, analysed, and resolved. This structured and transparent approach supports continuous improvement and builds confidence in the robustness and scalability of the T4M platform. The outcomes of the initial validation iteration will be reported in Deliverable D5.2. The final iteration results, along with lessons learned and guidelines for broader adoption, will be captured in Deliverables D5.3 and D5.4, respectively, contributing to the long-term impact and sustainability of the Tec4MaaSEs project.

Appendix A: Brief & Informed Consent Template

This appendix contains an English-language brief and informed consent template that can be translated and adapted to meet the specific needs of each Pilot Site.

Brief

This validation process is part of the Horizon Europe Tec4MaaSEs project to deploy a network of Digital Twins (DT), equipped with trustworthiness and cognition; to co-operate in a distributed manner within a value network as core enablers of Manufacturing-as-a-Service (MaaS) practices. The validation process is being conducted by [*Pilot Site*].

The procedure for the validation process involves interacting with the T4M solution to complete a set of test cases based on your specific role. Following this, you will be asked to complete questionnaires designed to gather insights into your user experience during the tasks. You may also be invited to participate in follow-up interviews, which will not be recorded unless explicit consent is obtained. In certain cases, you may be asked to contribute your domain expertise to help identify expected results and support the assessment of functional correctness.aThis validation process is carried out in accordance with the General Data Protection Standard 2018 and the data you provide will be stored and maintained by [*Pilot Site*] with complete confidentiality. [*Pilot Site*] will be the only staff with access to the personal data you provide in this process, which will be stored securely.

The validation process will include at least two iterations, each potentially involving multiple test cases. This consent form applies to all planned validation iterations and test cases.

The consent form requires your name only for initial identification until your data is processed. This means that you can withdraw your data from the validation process, without giving us any reason, until you complete the questionnaires and data collection templates associated with each test case. After this time, it will not be possible, as the data will be completely anonymous and will only be identified by a code number. Individual data will be reported in aggregate form so that no participant is identifiable and if individual quotations are used, they will be completely anonymous and unidentifiable to a particular individual.iIf you would like further information, please contact: [*Contact details of the Pilot Site Coordinator*].

For more information on the Tec4MaaSEs project please visit https://www.tec4maases.eu/

Thank you for your participation.

Consent

I understand what has been asked of me and I agree to take part in the validation process. I understand that I can withdraw and ask for my data to be removed for [*specify the time limit*] after submission, after which time I cannot because it will be completely anonymised.

I agree to the publication of my responses in anonymised form so that they cannot be traced back to me, as well as to screen video recording (without including voice) to assess and improve user experiences.

Printed Name: _____
Signature: _____
Date: _____

If a Participant is invited to take part in a photo session or interview to share their experience with T4M for dissemination purposes, an additional consent form must be provided, based on the following template.

Consent

I understand what has been asked of me and I agree to take part in the validation process. I understand that I can withdraw and ask for my data to be removed for [*specify the time limit*] after submission, after which time I cannot because it will be completely anonymised.

I agree to the publication of my photos and interviews for dissemination purposes: I will be informed prior the publication.

Printed Name: _____
Signature: _____
Date: _____

Appendix B: Generic Usability Questionnaire Template

This appendix contains an English-language version of a generic usability questionnaire extended from the System Usability Scale (SUS). It can be translated and adapted to meet the specific needs of each test case of component.

Participant number: _____
Task: _____
Date _____

Below are ten statements about your experience with the system. For each statement, please indicate your level of agreement using the scale below:

1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree

1. I think that I would like to use this system frequently.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly agree

2. I found the system unnecessarily complex.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly agree

3. I thought the system was easy to use.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5= Strongly agree

4. I think that I would need the support of a technical person to be able to use this system.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5= Strongly agree

5. I found the various functions in this system were well integrated.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly agree

6. I thought there was too much inconsistency in this system.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly agree

7. I would imagine that most people would learn to use this system very quickly.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly agree

8. I found the system very cumbersome to use.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	= Strongly agree

9. I felt very confident using the system.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly agree

10. I needed to learn a lot of things before I could get going with this system.

1 = Strongly disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly agree

The SUS questionnaire can be extended with a set of open questions to get a better insight.

Please can you tell us a bit more about your overall experiences doing the task?

Did you find the instructions easy / difficult to follow, and why?

Is there a part of the task that you found boring or tedious, and why?

What did you particularly like about the user interface? Why? Provide up to three examples.

What did you particularly dislike about the user interface? Why? Provide up to three examples.

If you could change anything about the user interface or the interaction flow to achieve the task what would you change?

Appendix C: Common validation test cases

This appendix presents the common validation test cases developed to evaluate the functionality, usability, and performance of the T4M components included in the first validation iteration across all Value Networks (VN1, VN2, and VN3). These test cases target core functionalities that are shared among the pilots, ensuring consistency in assessment and comparability of results.

Table 91: Validation: Initial iteration – TC.01.1

Concept	Description
Validation Test Case ID	TC.01.1
Test Title	User and Role Management Functionality Validation
Test Techniques	Scenario-Based Testing
Related User Story	US0.1
T4M Component	User Management
Test Objective	Validate that a super-user can successfully create, update, and delete user accounts and user roles, ensuring that the system enforces access rights appropriately. Functional validation, Role-Based Access Control (RBAC) Validation, UI/API Validation
Preconditions	• The super-user account exists and is authenticated. • The UI or API endpoints for user/role management are operational.
Participant role/quantity	Administration representative from each Pilot Site in all the VNs (super user).
Test Steps	1. Log in as a super-user. 2. Navigate to the user role management section. 3. Create a new user role (e.g., "IT Representative"). 4. Update the created role. 5. Delete the user role. 6. Navigate to the user management section. 7. Create a new user and assign them a role. 8. Update the user's information (e.g., email or role). 9. Delete the user.
Observation	• All user and role operations should return success messages and reflect immediately in the system. • Unauthorized actions by lower-privileged users must be blocked. • Any inconsistencies or failures should be logged and reported.
KPIs (1-N)	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0

Table 92: Validation: Initial iteration – TC.02.1

Concept	Description
Validation Test Case ID	TC.02.1
Test Title	User Account Access and Management Validation
Test Techniques	Scenario-Based Testing
Related User Story	US0.4
T4M Component	User Management
Test Objective	Validate that users can activate their accounts, log in securely, update their account information, and log out successfully. Assess the usability of GUI. Functional validation, Authentication validation, UI/API validation, Session Management Validation.
Preconditions	• A valid user account is registered in the system but not yet activated (for activation test). • The system's login and session handling mechanisms are operational. • User interface or API endpoints for login, profile management, and logout are available.
Participant role/quantity	All the participants that should interact with T4M on behalf of their organizations.
Test Steps	1. Receive activation email and click the activation link. 2. Set a password and activate the account. 3. Navigate to the login page and enter valid credentials. 4. Upon successful login, verify access to user dashboard. 5. Navigate to account/profile settings. 6. Edit account information (e.g., update email or display name). 7. Save changes and confirm update success message. 8. Log out of the system. 9. Attempt to access protected resources post-logout to ensure session termination.
Observation	• The activation link should be valid only once and expires after a defined period (e.g. 24h). • Login should be allowed only after successful activation. • Account updates must persist and reflect in the UI. • Logout should terminate the session and invalidate the token/cookie. • Unauthorized access after logout must be blocked. • Error messages and feedback must be clear and informative.
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.

Concept	Description
Success criteria	Number of critical defects=0

Table 93: Validation: Initial iteration - TC.03.1

Concept	Description
Validation Test Case ID	TC.03.1
Test Title	Consumer organization registration
Test Techniques	Scenario-Based Testing, Usability Testing
Related User Story	US1.1, US2.O1
T4M Component	Organization Management,
Test Objective	Validate organization registration data and storage. Assess the usability of GUI. Functional Testing, Form Validation, UI Workflow Testing, Data Integrity Testing
Preconditions	• The Administration Representative has access to the onboarding interface (e.g., web UI) and has logged in. • No existing registration for the same organization. • All system services related to Consumer registration are operational.
Participant role/quantity	Administration representative
Test Steps	1. Navigate to the organization registration wizard. 2. Input general organization information 3. Specify logistics preferences, e.g. target shipping location(s). 4. Upload required documents (e.g., certifications, company profile if applicable). 5. Review all entered information and submit the registration. 6. Confirm receipt of a success notification. 7. Attempt to re-register the same organization to verify duplication checks.
Observation	• If the Administration Representative is not related to an organization, they should only be able to see the organization registration wizard after logging in. • Each step in the wizard should validate required fields before proceeding. • Field validations (e.g., mandatory fields, format constraints) should be enforced consistently. • The system must prevent duplicate registrations based on key identifiers. • After submission, the registration should be stored correctly and trigger any downstream validation/approval workflows. • User feedback should be clear and guide correction of errors if input is invalid.
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0

Table 94: Validation: Initial iteration - TC.04.1

Concept	Description
Validation Test Case ID	TC.04.1
Test Title	Provider organization registration
Test Techniques	Scenario-Based Testing, Usability Testing
Related User Story	US1.3, US2.O1, US2.O3
T4M Component	Organization management, Dataspace Connector, Digital TwinValidate
Test Objective	Validate organization registration, and retrieval and storage of digital twin capability data across Data Space Connectors. Assess the usability of GUI. Functional Testing, Form Validation, UI Workflow Testing, Data Integrity Testing
Preconditions	• The Administration Representative has access to the onboarding interface (e.g., web UI) and has logged in. • No existing registration for the same organization. • All system services related to provider registration are operational.
Participant role/quantity	Administration representative
Test Steps	1. Navigate to the organization registration wizard. 2. Input general organization information 3. Define the manufacturing services catalogue. 4. Specify shipping countries and logistics preferences. 5. Upload required documents (e.g., certifications, company profile if applicable). 6. Review all entered information and submit the registration. 7. Confirm receipt of a success notification. 8. Attempt to re-register the same organization to verify duplication checks.
Observation	• If the Administration Representative is not related to an organization, they should only be able to see the organization registration wizard after logging in. • Each step in the wizard should validate required fields before proceeding. • Field validations (e.g., mandatory fields, format constraints) should be enforced consistently. • The system must prevent duplicate registrations based on key identifiers. • After submission, the registration should be stored correctly and trigger any downstream validation/approval workflows. • User feedback should be clear and guide correction of errors if input is invalid.
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0

Table 95: Validation: Initial iteration – TC.05.1

Concept	Description
Validation Test Case ID	TC.05.1
Test Title	Manual Search and Filtering of Manufacturing Service Providers
Test Techniques	Functional Testing, Search and Filtering Validation, UI Workflow Testing
Related User Story	US1.5, Extra functionality not initially identified in VN2
T4M Component	Search&Match, Organization management
Test Objective	Validate that consumer representatives can manually search for and filter manufacturing service providers based on specific criteria (e.g., manufacturing service type, location, rating) and receive a compliant list of providers.
Preconditions	• The Procurement Representative has access to the User interface and has logged in. • A set of providers is already registered and available in the system. • All system services related to provider searching are operational.
Participant role/quantity	Procurement representative
Test Steps	1. Navigate to the "Find Service Providers" tab. 2. Select desired manufacturing service type from a list or dropdown. 3. Apply additional filters such as preferred location, minimum provider rating, etc. 4. Submit the search query. 5. Review the returned list of providers that meet the selected criteria. 6. Select a provider to request quotation and start the Negotiation process. 7. Optionally, modify filters and perform another search to confirm dynamic update of results.
Observation	• Search results should strictly match the selected criteria. • Filtering options should be intuitive and responsive. • Provider profiles in the result list must display relevant summary information (e.g., name, service type, rating). • Search performance should be acceptable (e.g., < 2 seconds for result retrieval). • If no providers match the criteria, the user should receive a clear notification with the suggested next steps.
KPIs	
KPI	**Number of critical defects**
Measurement method	Issue management procedures
Calculation method	Number of critical defects in issue tracker.
Success criteria	Number of critical defects=0

Table 96:– Validation: Initial iteration – TC.06.1

Concept	Description
Validation Test Case ID	TC.06.1

Concept	Description
Test Title	Functional Validation and Data Flow: Optimisation Service to Post-Processing Analytics.
Test Techniques	Workshop-Based Validation
Related User Story	US1.5, US2.P2
T4M Component	Optimisation Service → Predictive / Proactive Analytics
Test Objective	To evaluate the system's behaviour and interoperability through a live demonstration of key features and workflows to gather immediate feedback from stakeholders.
Preconditions	• The Optimisation and Analytics presenter has access to the User interface and has logged in. • A set of providers is already registered and available to the system • A set of new requests arrives to the system, accompanied by the appropriate data, i.e., delivery dates, parts, manufacturing processes, optimisation criteria, product specifications • A collection of accurate providers' data, by different components (Search&Match, Dataspace connector, and Bill of Processes Generator) is also available in the system, including: machine availability time windows, precedence constraints between the machine processes, processing times of each process, machine eligibilities, plant locations, transportation times between plants • Creation of the optimisation input • Definition of the analytics criteria
Participant role/quantity	Procurement representatives Optimisation Presenter: Optimisation Service component owner. Analytics Presenter: Predictive / Proactive Analytics component owner.
Test Steps	1. Component owners Introduce test scenario to participants. 2. Optimisation component owner simulates system input triggering Optimisation Service. 3. Participants observe system response and data transmission to analytics. 4. Analytics component owner presents and explains the results. 5. The Optimisation and Analytics component owners review and discuss results with participants. 6. Participants provide feedback. 7. The Optimisation and Analytics component owners record meeting minutes, gather stakeholder feedback, and collect system logs
Observation	Both components perform as expected under the simulated conditions. Workshop participants confirm functional correctness and discuss observed outcomes and improvements.
KPIs	
KPI	**Functional correctness**

Concept	Description
Measurement method	Compare system response to known expected action (reviewed live by domain expert)
Calculation method	*Accuracy (%) = (Correct Decisions / Total Scenarios) × 100*
Success criteria	*≥ 95% functional correctness*