Tec4MaaSEs

Technologies for Manufacturing as a Service Ecosystems

Deliverable D2.1

Reference cases and actionable models for reconfigurable value networks and service decomposition v1

WP2: Reference framework, specifications and core enablers

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Executive Summary

The Tec4MaaSEs project embraces key enabling technologies to support Manufacturing as a Service (MaaS) ecosystems. At its core, it develops a network of Digital Twins (DTs) that possess both trustworthiness and cognition, allowing them to work collaboratively within a distributed value network.

This deliverable presents the requirements of the Tec4MaaSEs project as derived from the requirement elicitation process conducted in the course of WP2 and in particular Task 2.1 (Analysis of use cases, KPIs and requirement specifications) and Task 2.2 (Actionable models for reconfigurable value networks and service decomposition). In particular it (a) presents the requirements for the to-be developed system that will enable them to transition to a Manufacturing as a Service approach and (b) identifies and elaborates on the Key Performance Indicators (KPIs) that will be used to evaluate the Tec4MaaSEs project. Furthermore (c) it presents an initial identification of applicable business models for MaaS and in particular for the pilots as well as (d) presents the outcomes of a literature review on Manufacturing KPIs and a mapping to the KPIs of the pilots.

Within the deliverable a detailed description of the industrial pilots and their business cases offers a wide range of important and relative information towards the creation of the requirements and subsequent user stories and use cases that will in turn be transformed at later stages into the system that meets the needs of the pilots. Furthermore, the current status of each pilot is presented with details on the current version of production (to be turned into MaaS), the systems involved in the current processes, and how they (will) contribute to the (new) manufacturing processes as well as the actual users that are involved in the production process, their roles, responsibilities and potential use of the Tec4MaaSEs solution. In addition, and per pilot case the different KPIs are presented including their definition and calculation method as well as their baseline to enable Tec4MaaSEs to have a rigorous evaluation in due time.

Three different value networks (i.e. pilots) are involved in the Tec4MaaSEs project and are used as the focal point for the requirements elicitation process.

- **Value Network 1 (VN1)**: Electronic Cards for White Goods featuring 4 Companies: 5 User Types, 11 User Stories, 15 Use Cases, and 4 KPIs
- **Value Network 2 (VN2)**: Additive manufacturing for Injection Companies featuring 3 Companies: 3 User Types, 11 User Stories, 15 Use Cases, and 4 KPIs
- **Value Network 3 (VN3)**: Facilities Construction for the Hydrogen Market featuring 2+ Companies: 3 User Types, 7 User Stories, 18 Use Cases, and 4 KPIs

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Acronyms and Abbreviations

Acronym	Description
AM	Additive Manufacturing
AMS	Additive Manufacturing Service
BC	Business Case
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CNC	Computer Numerical Control
DT	Digital Twin
EDM	Electrical Discharge Machining
EPC	Engineering – Procurement – Construction
ERP	Enterprise Resource Planning
IM	Information Model
KPI	Key Performance Indicator
LEP	Large Energy Producer
LMD	Laser Metal Deposition
MaaS	Manufacturing as a Service
MachS	Machining Service
MES	Manufacturing Execution System
PIMS	Plastic Injection Moulding Service
PRB	Package Responsible Buyer
PRE	Package Responsible Engineer
T4M	Tec4MaaSEs
UC	Use Case
US	User Story
VN	Value Network

Glossary

Term	Description
AM final part	It refers to a component or part that is manufactured using additive manufacturing (AM) techniques and has been finished using machining process to meet geometrical and surface requirements imposed by the customer serves as an intermediary or intermediate step in the production process. It involves both Additive Manufacturing and machining processes.
AM intermediate part	It refers to a component or part that is manufactured using additive manufacturing (AM) techniques and serves as an intermediary or intermediate step in the production process. It involves only Additive Manufacturing process.
Manufacturing service	It involves providing manufacturing capabilities following the "as-a-service" paradigm.
Manufacturing service request	Having providers onboard the T4M, the consumers can request their need for a new manufacturing service
Selection criteria	Details for products in a manufacturing request such as quantity to be produced, and applicable selection criteria (e.g. mixture of providers, time of delivery etc).

1 Introduction

This deliverable outlines the business cases and associated user requirements for the Tec4MaaSEs (T4M) project, derived from its industrial pilots, along with the Key Performance Indicators (KPIs) that will be used to assess how effectively the T4M project enhances their operations and addresses their needs. The submission of this document (D2.1) is part of WP2 (Reference Framework, specifications and core enablers) and is the result of Task 2.1 (Analysis of use cases, KPIs and requirement specifications), delivered at the end of month 8 of the project.

1.1 Purpose and Scope

The main objective of this deliverable is to provide a detailed description of the industrial pilots and their corresponding needs within T4M. In this regard, the deliverable aims to provide a solid foundation for the technical development of the T4M System and its components, enabling them to identify and subsequently cover the needs of the corresponding industrial partners. To this end, this document offers a wide range of information such as:

- An overview of the manufacturing systems examined within the T4M project and the associated production tasks.
- The manufacturers' specific requirements stemming from these tasks, detailed in User Stories (USs) and further elaborated in Use Cases (UCs).
- The personnel and their roles involved in completing these tasks.
- The production units (e.g., machines, robots, etc.) used in the corresponding pilot environment.
- The current systems in use, along with their purpose of use and the corresponding connection type.

The deliverable also outlines general-purpose user requirements identified for configuring and accessing the T4M System, which will be designed and built to meet these needs. In addition, the deliverable presents a detailed account of the manufacturing KPIs that will be used to evaluate the outcomes of the T4M project within each industrial pilot environment. This presentation includes:

- KPI definition
- Description of the corresponding calculation method for the KPI
- Related data and corresponding availability to calculate the KPI value
- Baseline value of the KPI, corresponding to the as-is situation
- Goal value for the KPI, corresponding to the to-be situation, i.e., after the implementation and commissioning of the T4M System.

These KPIs are designed to measure the impact of implementing T4M in the respective manufacturing environments.

1.2 Methodology

As outlined in the previous section, this deliverable aims to detail user requirements and corresponding KPIs for the T4M project. It adopts a user-centric perspective without assuming technical developments from the T4M System. The T4M project involves three distinct Value Networks (VNs) encompassing eight different companies. These industrial pilots share many similarities but also address complementary issues. They were selected during the T4M proposal phase to cover a broad spectrum of modular manufacturing and distributed control themes. Therefore, each value network has clear boundaries, and our goal is to gain a comprehensive understanding of them.

The requirements elicitation process typically involves multiple steps and may require iterative rounds to ensure a thorough understanding, identify gaps, and incorporate additional insights. Figure 1 illustrates the user requirements elicitation process followed within T4M. This process was conducted separately and concurrently for each of the three value networks, as there is no overlap between them. Interaction between manufacturers is necessary for all value networks, because they involve collaboration between many distinct departments inside the industrial partners.

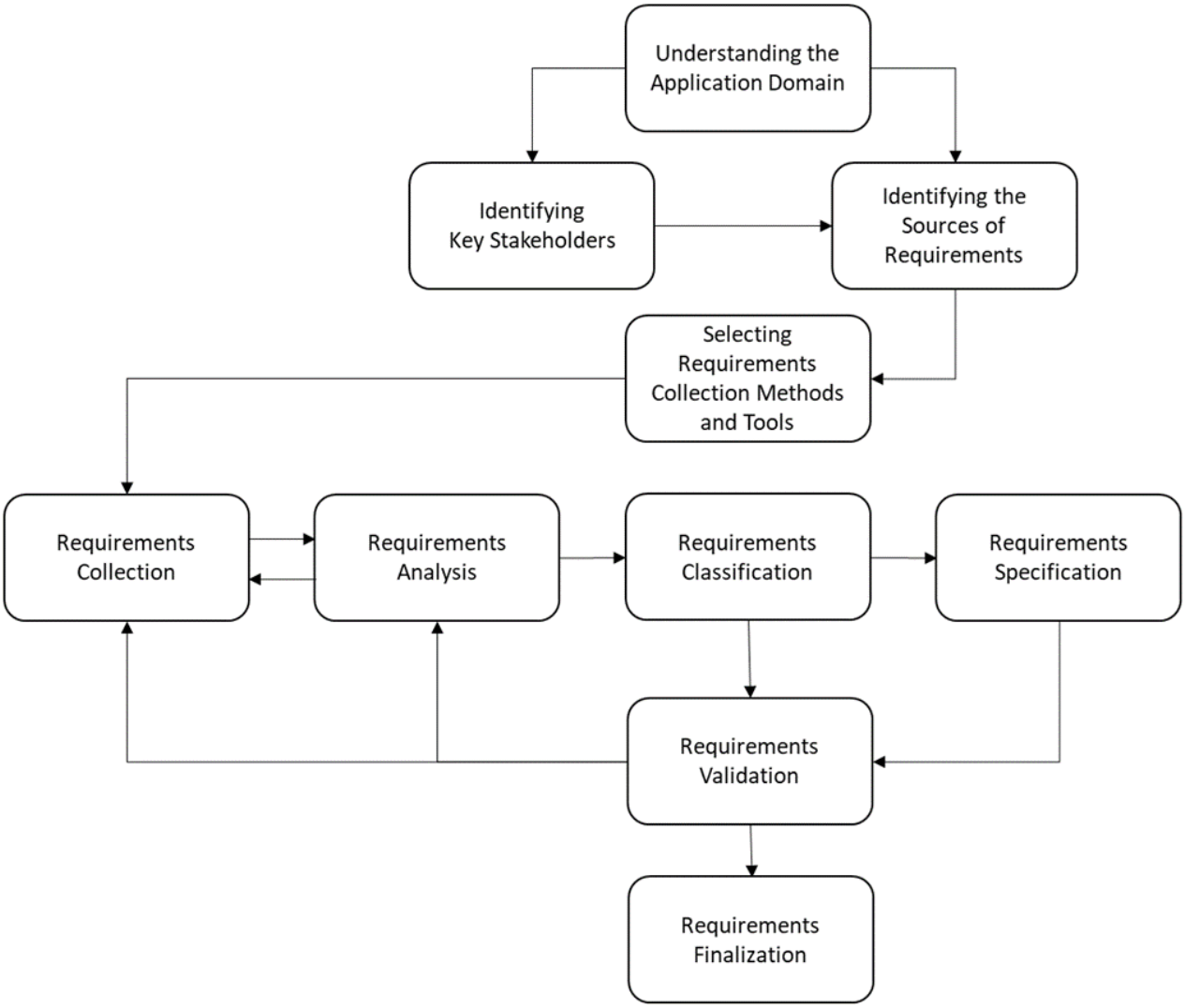


Figure 1: The User Requirements elicitation process of T4M

Our strategy then focused on identifying crucial stakeholders who would help identify and comprehend user needs, along with any supplementary requirements. Within manufacturing organizations, these stakeholders encompassed experts from their innovation departments, production managers, engineers, and other personnel from production sites. Additionally, personnel from their ICT departments played a role in providing essential insights into information systems and related connectivity.

Similarly, key stakeholders among T4M technological partners were pinpointed for their expertise in implementing manufacturing solutions and their active role in designing and developing the T4M System. Their involvement was crucial to facilitate value network users in defining business cases, gaining deeper insights, and ensuring the refinement and validation of collected user requirements.

Prior to commencing the actual process of gathering and analysing user requirements, we carefully selected suitable methods and tools for requirements collection. Given the diverse expertise and detailed needs across all pilots, we opted to use two fundamental methods: distributing questionnaires to gather initial data and conducting subsequent semi-structured interviews based on these responses to delve deeper and clarify any ambiguities. Thus, the process of eliciting user requirements involved gathering initial information through questionnaires and conducting follow-up interviews to explore further details and insights.

In more detail, regarding the questionnaires and subsequent interviews:

- It was determined that each questionnaire would feature open-ended questions, allowing respondents to elaborate and provide as much detail as needed.
- The content of each questionnaire was discussed and finalized in collaboration with all technical partners involved in the process of eliciting user requirements.
- Rather than requesting multiple questionnaires from different stakeholders within the same manufacturing organization, a single questionnaire was requested to be completed by the organization.
- This approach required the manufacturing partners to aggregate requirements internally, ensuring a unified approach to capturing user needs.
- This decision was motivated by several factors:
    a. Requiring a single questionnaire prompted internal discussions within each manufacturing organization, enhancing understanding of the project and its requirements across different departments and stakeholders.
    b. Using a unified document facilitated an initial round of refinement and validation of the input received.
    c. As partners in the T4M project, all manufacturing organizations had personnel deeply involved in the requirements elicitation process (i.e., Task 2.1), ensuring their commitment and active participation.
- Particularly for every value network, bilateral meetings were conducted between collaborating manufacturing partners before completing their questionnaires.
- Following the receipt of each questionnaire, an initial analysis was performed, followed by scheduling semi-structured interviews. These interviews typically involved a group of key stakeholders from every manufacturing organization, facilitating detailed discussions on questionnaire responses and addressing any emerging questions.
- If any questions remained unanswered by the end of an interview or if further clarification was needed, additional follow-up interviews were scheduled and conducted as necessary.

During the elicitation process of T4M, a specialized questionnaire was distributed to all manufacturing partners. This questionnaire consisted of three sections addressing the three different types of required information. More specifically the **Industrial Value Network section** covered topics including an overview of the organization, its products, its production processes, and stakeholders; descriptions of current and future states; details on existing ICT infrastructure and/or DTs; the T4M Business Proposition; and considerations of data sovereignty including eligible authorizations as well ethics issues. Some aspects of this questionnaire were broader in scope beyond Task 2.1, aiming to provide a comprehensive perspective from industrial partners on T4M. The **Existing Systems section** involved mapping systems relevant to each pilot to use cases and finally, the **KPIs part of the questionnaire** was developed based on KPIs outlined in the Description of Action and those mentioned in the Industrial Value Network Questionnaire. It prompted industrial partners to review these KPIs, suggest additions if necessary, and provide detailed information including definitions, calculation descriptions, related data sources, and baseline and goal values for each KPI.

The questionnaire template for each VN is provided in the Annex section.

As previously mentioned, follow-up semi-structured interviews were conducted to gain deeper insights into the gathered information. Specifically, each partner participated in two interviews focused on Value Network requirements, followed by one interview each regarding the existing systems questionnaire and the Value Networks' KPIs questionnaire.

It's important to note that after each round of collecting requirements (e.g., through questionnaires), a corresponding requirements analysis was conducted. This analysis aimed to identify areas needing further explanation or where gaps might exist. Subsequently, this process informed the next round of requirements collection (e.g., through semi-structured interviews), creating an iterative interaction between these phases, as illustrated in Figure 1.

The initial outcome of the requirements analysis aimed at capturing user requirements was the classification of each VN's requirements through a comprehensive set of user stories. These USs followed a standard format, presenting a first-person narrative that included:

- The user profile addressed by the US.
- A clear description of what the user aims to accomplish.
- The rationale behind why this was necessary.

For instance, a US from VN1 exemplifies this approach: "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."

These USs underwent a rigorous review, analysis, iterative refinement, and validation process involving key stakeholders from the industrial pilots. This process occurred both offline (through shared document comments in D2.1) and during regular discussions with the partners.

Once validated, the USs were further analysed to derive corresponding requirements specifications in the form of use case descriptions. Each use case was meticulously detailed, including:

- UC identifier.
- UC name.
- Brief description.
- Primary actors.
- Pre-conditions.
- Post-conditions.
- Basic flow.
- Alternative flows as necessary.

This standard format ensured that all essential information was captured and presented clearly for each UC.

1.3 Structure of the document

The document is structured as follows:

- **Section 1** Introduces the Deliverable and presents the scope of the document and relation to other deliverables
- **Section 2** provides a concise overview of the T4M pilots and their objectives.
- **Section 3-5** refer to VNs 1-3, respectively.

- **Section 6** presents general-purpose user requirements related to the configuration of the T4M System
- **Section 7** offers a literature review that validates the pilot requirements concerning their applicability in relevant settings
- **Section 8** concludes this deliverable with relevant Business Models and related concluding remarks.

A note on the document: Some USs and UCs in Section 6 are referenced as pre-conditions in the UCs presented in Sections 3-5. While this forward-referencing might seem odd to some readers, it highlights that the focus of both this deliverable and the T4M project is on addressing real manufacturing needs, as motivated by the VNs described in Sections 3-5. The systems, technologies, tools, and algorithms of the T4M approach are facilitators to addressing those needs. Presenting the manufacturers' requirements first (Sections 3-5) and then the system configuration requirements (Section 6) illustrate this focus effectively.

2 The Tec4MaaSES Value Networks and Concept

2.1 Overview of Tec4MaaSEs value networks

In Tec4MaaSEs (T4M) three distinct value networks (VNs) are included with high potential to benefit from the transformation of traditional manufacturing to manufacturing as a service. Each VN consists of different companies with mutually beneficial interests that belong to the same supply chain acting as a supplier or consumer. In particular the three VNs are:

- VN1 Electronic cards for white goods,
- VN2 Additive manufacturing for injection moulding and
- VN3 Facilities construction for the hydrogen market.

The three VNs are briefly presented in the following paragraphs.

VN1: Electronic cards for white goods

The first VN consists of four factories in the field of white goods and electronic cards production. In white goods a number of electronic boards (EB) are needed which are highly tailored to the specific appliance they will be put in. These electronic boards are produced by factories (in our case the providers) from the combination of over 500 components (e.g. PCBs, transistors etc.) and then transferred to other factories (in our case the consumers) that utilize the received EBs in the white goods appliances they in-turn produce. Currently the production process of these EBs poses a problem as different consumers, update their demands in a manner that creates problems and bottlenecks for the providers. In this VN Arcelik Çerkezköy (AC) and Karel Electronics (KE) are the providers – i.e. producing the electronic boards from components and shipping them to consumers. On the other hand, Arctic Romania Washing Machine Factory (AR) and Arcelik Bolu Cooking Appliances Factory (AB) are the consumers who provide their demands and the time they need the EBs. For this VN, T4M will enable the swift interaction of consumers and providers towards the production of the needed EBs for their appliances.

VN2: Additive manufacturing for injection moulding

The second VN consists of three companies ERREKA Plastics, Moldes URA and Tekniker in the field of machining and additive manufacturing (AM) of injection moulds. ERREKA Plastics is dedicated to designing

and manufacturing plastic injection components for a wide range of industries. Moldes URA is an SME specialized in the design, feasibility assessment, and manufacturing of moulds for different sectors. Tekniker is a research centre specialised in manufacturing and its manufacturing shop floor involves several manufacturing resources that can provide both Additive Manufacturing Services (AMS) and Machining Services (MachS). AM has many advantages over more conventional manufacturing methods in the injection moulding sector, and clearly, its use can speed up the time to market and reduce costs when utilized to produce some of the parts of the mould and avoid the storage of mould spare parts. Introducing additive manufacturing can reduce/eliminate the need of expensive spare part inventories and reduce the cost and lead time in the production of injection moulds but it introduces new challenges such as the need of high-cost investment or the need of additional finishing processes. Contrary to traditional marketplaces for additive manufacturing services, T4M solution will support fast, ad-hoc reconfiguration of the supply chains (including logistics) based on real context (e.g., changes in the real capacity status of the providers or forecasting), enabling resilience and responsiveness of the formulated industrial value networks. VN2 aims to illustrate how a MaaS Marketplace based on T4M technologies leverages the flexible (re)configuration of value chains in the injection moulding domain, 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 manufacturing as a service (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.

VN3: Facilities construction for the hydrogen market

The third VN consists of one focal company, the EPC Contractor, and their suppliers of equipment packages. The construction of a facility for large energy production is a capital project in the range of billions and as such it is highly specialized. Therefore, in the production of such facility intense interactions need to take place between the EPC Contractor (that is the consumer) and their suppliers. Each supplier is requested to provide a proposal for specific equipment packages that belong to the facility and will interact with other equipment to eventually constitute a facility. Overall, per equipment package one supplier is awarded the contract to develop and deliver the specialized equipment and from then on, the production, delivery and acceptance of the equipment takes place. In this process bilateral interactions between the contractor and the supplier(s) take place based on a very broad set of documents that describe the equipment. These interactions are time consuming and prone to errors leading to the need for a system that streamlines these interactions and enables them to be conducted with agreed Information Models (IMs).

The description of the three value networks presented above, highlights an interesting feature inherent in T4M. Specifically, one could map the three Value Networks, VN#1 to VN#3, onto the three fundamental levels of planning in operations management; that is, operational, aggregate, and strategic planning.

In particular, VN#1 focuses on operational planning at the most basic level of operations, specifically for the production of a single type of product, the electronic board for white goods (albeit, under various variations). The four involved factories (stakeholders, including two consumers and two providers) aim to coordinate their actions to improve the alignment of supply and demand for electronic boards on a daily basis.

On the other hand, VN #2 involves three stakeholders, each of whom may have multiple roles as consumers and/or providers within the manufacturing sector, particularly in additive manufacturing. In this case, the emphasis is on the planning and production of moulds for plastic components, an intermediate process related to aggregate planning in the plastic components sector. Additionally, we are highly interested in the

available production capacity, whether in machining or additive manufacturing, with the goal of reducing idle periods at the aggregate planning level.

Finally, in VN #3, there is a single stakeholder, an EPC contractor (Aibel), which constructs large energy production facilities on behalf of third parties. In this case, the challenge is at the strategic planning level, as T4M is intended to facilitate negotiations after contracts for the construction of the facility have been signed. The aim is to streamline, standardize, and digitize the negotiation process with various suppliers of both standard and customized equipment. These bilateral interactions between the contractor and the supplier(s) should be transformed into specific agreed-upon Information Models, thus positioning the entire process of the specific VN at the upper (strategic) level of operations management.

2.2 The Tec4MaaSEs Concept

Tec4MaaSEs (T4M) envisages the transformation of traditional manufacturing to Manufacturing as a Service (MaaS). On that account, and as identified through the requirements elicitation process, a system that will bring together providers and consumers under different matchmaking scenarios would enable them to (a) as provider to utilize their production capabilities as well as spare capacities and (b) as consumer to request manufacturing services from available providers.

Therefore, T4M initially enables providers to register their production capabilities in order for the system to match them with potential manufacturing requests. On the other hand, consumers upload their needs for production, T4M decomposes the product under discussion and together with service-related parameters initiates a matching of the request to potential providers that are eligible to produce it. Once the matching is successful a process of negotiation begins, in which the consumers are prompted to update their request by including additional information, such as price, time of delivery, etc. Thus, the consumer(s) can choose among the list of suggestions made by T4M while at the same time providers can maximize the utilisation of their assets.

Once an agreement (a T4M contract) is reached the T4M platform also enables the consumer and provider to follow up on the contract and respond to any unforeseen events at the different phases of the contract execution by directly utilizing information from both the consumer's and provider's production and distribution processes. Lastly upon successful completion of the contract a follow up takes place in the scope of T4M that enables both consumers and providers to provide information on the contract execution towards a mutual evaluation.

We note that DTs is a core concept for the realization of T4M and thus at this point we highlight that this preliminary stage of our analysis envisages a network of interconnected Digital Twins (DTs) within T4M, encompassing one DT for each member of the value network.

It is worth mentioning that the elicitation process eventually led on a further adaptation and specification of the original KPIs. In this respect, the adapted KPIs focus on the established information exchange processes and are representative of the corresponding VN goals in the scope of T4M.

3 Value Network 1: Requirements and KPIs

3.1 Description

The primary focus of the first 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 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 Arcelik Çerkezköy Electronic Factory (AC) and Karel Electronics (KE), respectively, responsible for designing, developing, and supplying EBs to the consumers for the production of their final products. These electronic boards are produced through electronic materials and components (almost 500 different materials) and once produced they are respectively shipped. The majority of companies are part of the Arcelik group (the consumers and one producer), making them the central focus. Karel will be closely aligned with Arcelik to ensure the attainment of the established targets under a MaaS scenario of EBs' production. However, as the T4M scope is to transform the current process into an "as a service" approach, all three companies (AC, AR, AB) of Arcelik will be treated as independent consumers/ providers.

Arcelik is a leading player in the European Home Appliances sector with a production volume of more than 30 million household appliances produced annually by a complex value network which includes Arcelik's 30 factories spread around over 9 countries. Among the various parts that go into Arcelik's products, EBs are among the most fundamental ones and can be produced by Arcelik or by one of its suppliers. Arcelik's own factory in Çerkezköy (AC) produces a major portion of the EBs needed within the value network but at the same time outsourcing of EBs is another alternative as production capacity cannot always meet demand. Karel has currently the largest share among Arcelik's outsourced EBs.

Arcelik Bolu (AB) stands as a cornerstone of the company's manufacturing process. Specializing in the production of cooking appliances, this facility showcases Arcelik's commitment to innovation, quality, and sustainability. Today, the factory, which provides employment opportunities for 2.500 people and has a production capacity of 5.5 million units annually, operates with 22 auxiliary industrial enterprises, exporting to 122 countries. Equipped with state-of-the-art technology and adhering to rigorous quality standards, the factory produces a diverse range of cooking appliances tailored to meet the evolving needs of consumers.

Arctic Romania (AR) similarly, is the leader of the Romanian home appliance market, as it is one of the strongest companies in Romania, and one of the most important employers and exporters in the SE European country. With approximately 4,300 employees, the company exports 83% of its total production to over 85 countries. The company owns the largest household appliance factory in continental Europe, the Găești unit producing so far over 36 million refrigerators. It also owns the only Industry 4.0 factory in Romania and one of the few in Europe, the factory in Ulmi, Dâmbovița, with a production capacity of 2.2 million units per year.

Karel Electronics (KE) is a leading electronic factory based in Turkey. Specializing in the production of electronic components and devices, KE is renowned for its innovative technology and high-quality products. With a focus on design excellence and cutting-edge manufacturing processes, the factory delivers a wide range of electronic solutions to meet the diverse needs of its customers. Committed to customer satisfaction and technological advancement, KE continues to play a significant role in the electronics industry both locally and globally.

The benefits of T4M in the present VN will be examined through a variety of actual use cases provided by Arcelik, which will be designated from the interactions between producers and consumers.

Within this VN, AC and KE are responsible for the manufacturing and distribution of EBs to the factories of Bolu and Arctic. Production planning in Çerkezköy is organized once per month via an ERP system that logs inventory and demand data from the consumers and is based on a flexible time window specified by the providers, allowing for alterations of their order. Karel on the other hand receives quarterly orders from each consumer and allows for their revision at most twice per month. The finalized products are sent to Bolu daily or weekly via trucks and minivans. In case of Arctic in Romania, deliveries take place once or twice per week depending on the demand, using large trucks. It is important to note that although both the consumers and one of the providers belong to the same company (Arcelik), in terms of their day-to-day operation they work independently meaning that each consumer is responsible for their own purchases of EBs and the ordering takes place in a decentralized manner and as such are a prime candidate for the T4M scope.

Overall, the aforementioned processes require integrated synchronization mechanisms, as critical steps are currently conducted in a sub-optimal and ad hoc way and without proper monitoring, leaving room for potential errors, disruptions of the whole value chain and not optimized timeframe. On that account, the VN1 goal is to improve coordination and communication with providers in the context of new EBs ordering, production and distribution, by offering their production capacity as a resource to be exploited by the EB consuming plants, in a manner that increases both throughput and resilience. The envisaged way to achieve this is through a MaaS approach by exploring DTs models inside the VN and/or production plants, in order to acquire, process and distribute all the information from consumers to the involved stakeholders faster and more efficiently.

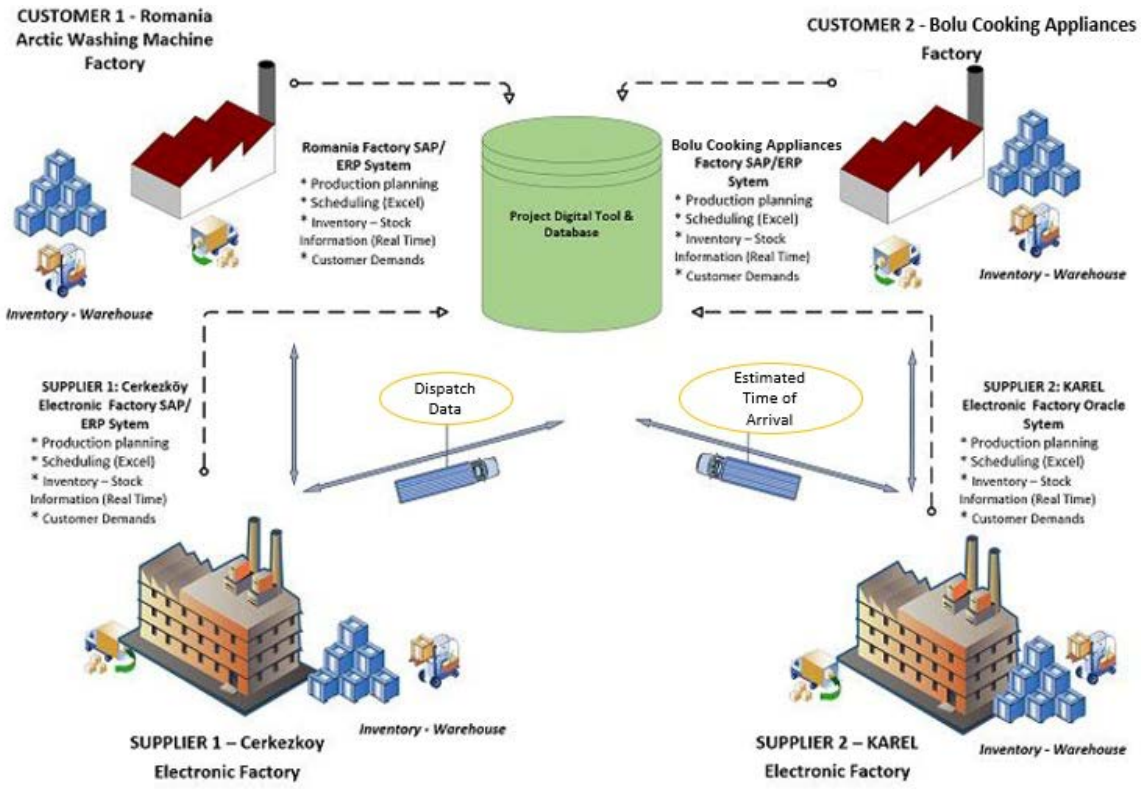


Figure 2: VN1 Ecosystem

To exemplify the breadth and depth of the innovation required in order to achieve the aforementioned, Figure 2 presents an indicative flow network of the interactions between, providers and customers, respectively. Currently as provider AC cannot meet the demand for EBs from all factories (including AR and AB) Arcelik has placed contracts with other providers (i.e. Karel). On that account and having the initial contract in place each Arcelik factory – acting as a consumer – can independently ask for the production of the needed EBs from both AC and KE (and other factories). However, as the consumers in our case (AR and AB) order independently, and without internal factory-to-factory communication a bottleneck occurs when AC receives orders they cannot meet. In parallel, the standing contract with Karel is being underutilized. On that account, T4M will introduce a new ordering and production process which optimizes the utilization of capabilities and production abilities. The ordering process for EBs begins with managing demand data. The consumers, (AR and AB), send their demand data in an Excel table via email once per month. AC Plant receives these ordering requests and has to fulfil these demands within a tolerance that depends on the order status (finished, semi-finished, etc.). AC offers some flexibility in the original production plan, providing consumers with a flexible time window to make alterations to their orders because they must expect possible disruptions in their production and shipping processes, such as machine breakdown in continuous assembly line, fluctuations in demand, shipment delays, revised demands etc. The initial phase of MaaS focuses on identifying the production, capabilities, and the provider's ability to produce, defining the lifecycle specifications of EBs, and the necessity for operational DTs and their interactions through a specialized metamodel. In this preliminary stage of analysis, a network of interconnected DTs within T4M is envisioned, encompassing one DT for each plant in the VN. The T4M platform will be accessible to consumers (AR and AB) via a user interface, allowing them to search among a list of approximately 130 EB variants, those that fulfil their requirements. Considering facility locations and various pre-agreed QoS criteria, service demand for EBs will be matched with the offerings from AC and KE. The planning and scheduling of services will be optimized using data-driven methods that incorporate proactive and predictive analytics to handle disruptions like demand fluctuations, machine breakdowns, and logistic issues as derived from the uploaded capacities of the producers and the general capabilities for EBs' production. The final output will provide detailed information on the selected value network configurations (i.e. mixture of EBs productions from the different providers) for the requested service. All participating plants will optimize thus their production and distribution processes.

Having described the overarching goal of the VN1 the following sections provide a detailed examination of the steps involved in the associated processes, the role of the T4M solution and the involved stakeholders. The overall phases are illustrated Figure 3.

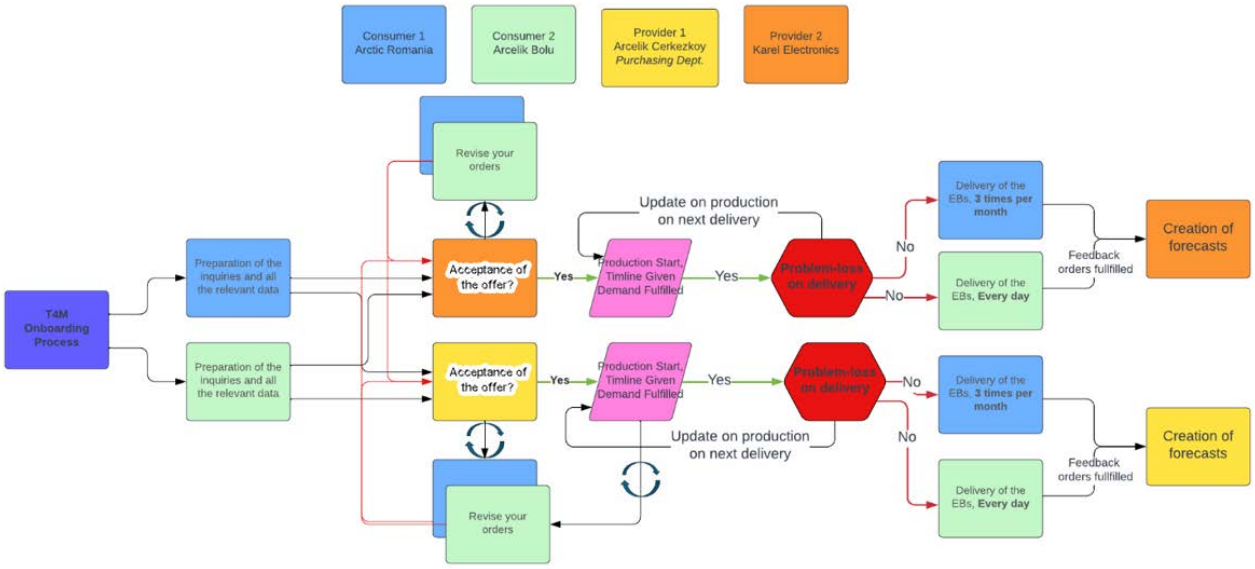


Figure 3: VN1 Phases of the new interactions between different facilities

Provider 1: Arcelik Cerkezkoy Electronic Factory (AC)

AC, serving as Provider 1, plays the main role for the two consumers as in day-to-day activities, prior to a MaaS approach, all consumers that belong to Arcelik directed their requests through a specialized AC department that allocates mixtures of EBs to be produced within the AC factory and from other providers. However, this will be updated under a MaaS approach and independently consumers will ask providers through T4M. Additional information relevant to Provider 1 includes several critical points. Firstly, production planning is conducted once a month, during which inventory and demand data are logged. However, there is no ERP-ERP synchronization with other factories, leading to a lack of coordination. Furthermore, the shipment of EBs is not monitored and is uncoordinated with production schedules leading to the need of the identification of an estimated ETA on the EBs that are to be produced. Furthermore, each EB is tailored, eliminating the potential for repurposing.

There are also challenges with unexpected demand fluctuations that Çerkezköy's supply cannot meet. The data from production planning are not effectively utilized, as there is no method for predicting failure to provide EBs and/or logistic problems. This lack of foresight can disrupt the entire VN.

Despite these issues, the factory does allow for some flexibility in the original production plan, providing consumers with a flexible time window to alter their orders. However, there are no DTs or MaaS approaches implemented yet. Based on production capacity and material stock availability, the plant can adjust its production plan and offer consumers a flexible timeframe to make changes to their orders.

Provider 2: Karel Electronics Factory (KE)

Karel Electronics, serving as Provider 2, plays a critical role for two main consumers: Arctic and Bolu. For Arctic, orders are communicated through annual forecasts with revisions every three months. Monthly orders are finalized in the last week of the preceding month. Logistics for the AR Facility involve allocating 12 boxes per pallet, with trucks transporting 15 to 18 pallets and trailers up to 52 pallets. With monthly orders between 60,000 to 65,000 units, the facility executes at least three shipments per month. The AR facility orders various products, including B7S Arcd, D7S display, C7S display (top-selling product), C7S power (quality

top-selling product), Prolog C7S, Prolog Drive, Prolog Drive 2, and Prolog Power (Same products ordered to AC).

For AB, orders are communicated via annual forecasts and revised every two months. Finalized orders include a six-week lead time from the shared date and are revised weekly. The AB Factory orders for an average of 36 product groups and 52 different products (Same products ordered to AC). The highest volume products include *Beast_Timer, Beast_Pro, B14_Good_Plus,* and *Sky_Fire_Etna*. Six product groups account for 82% of total demand. Shipments are made daily by the transportation company contracted by Arçelik, with vehicle organization based on shipment volume intensity, averaging 4-5 pallet shipments daily, which varies with seasonal stock increases.

Additional information relevant to Provider 2 includes Karel's spare capacity in terms of machine availability and raw materials. Therefore, implementing efficient ordering / production and logistics by utilizing a MaaS approach and synchronization through DTs could enhance real-time monitoring and utilization of spare capacity, could help meet demand more effectively. Addressing these areas would enable Karel Electronics to strengthen its role within the value network, ensuring more reliable and efficient support for its consumers.

Consumer 1: Arctic Romania Washing Machine Factory (AR)

The role of Consumer 1, involves several key responsibilities. As an input, the factory receives Electronic Boards (EBs) from Çerkezköy once or twice a week, with a total capacity of 64 pallets. Additionally, it receives EBs from Karel four times a month, based on three-month forecasts, with a total capacity of 33 pallets per articulated lorry. As outputs, the factory provides inventory and demand data to Çerkezköy and Karel annually. Additional details relevant to the value network for Consumer 1 include the production planning that is conducted once a month, utilizing forecasts that span three months and is managed via ERP systems. However, there is no synchronization of ERP systems with other factories, leading to coordination challenges. The demand from Arctic cannot be fully met, which affects both their internal needs and the ability to accommodate consumer revisions. This misalignment can lead to production inefficiencies and potential delays. The lack of ERP-ERP synchronization with other factories creates significant hurdles in achieving seamless integration and coordination across the supply chain. With the current setup, shipments of EBs are not adequately coordinated with production schedules, leading to potential bottlenecks and inefficiencies in the supply chain. Despite these challenges, the factory strives to maintain flexibility in its production plans, allowing some leeway for order alterations within the given timeframes.

Consumer 2: Arçelik Bolu Cooking Appliances Factory (AB)

The Bolu Cooking Appliances Factory receives EBs from Çerkezköy once a day, with a total capacity of 5 pallets per shipment. It also receives EBs from Karel once a month, based on three-month forecasts, with the total capacity yet to be specified. The factory provides demand data to Çerkezköy and Karel on a weekly or monthly basis. The factory conducts production planning once a month, utilizing three-month forecasts. This planning is managed through ERP systems. However, there is no synchronization of ERP systems with other factories, leading to coordination challenges. Bolu's demand cannot be fully met, impacting both internal production requirements and the ability to accommodate consumer revisions. This shortfall can lead to inefficiencies and potential delays in the production process. The lack of ERP-ERP synchronization with other factories poses significant hurdles in achieving seamless integration and coordination across the supply chain, affecting overall efficiency. The current setup does not sufficiently coordinate EB shipments with production schedules, potentially causing bottlenecks and inefficiencies in the supply chain. Despite these issues, the

factory strives to maintain flexibility in its production plans, allowing some adjustments to orders within specified timeframes. There is no implementation of Digital Twins (DTs) or a Mobility-as-a-Service (MaaS) approach. This absence limits the factory's ability to fully optimize the supply chain, including real-time monitoring and predictive maintenance.

Having described the overall parameters of the providers and consumers in VN1, the main phases of on-demand manufacturing service procurement are described below.

Phase#1. Providers'/Consumers' onboarding process

The T4M Marketplace will allow providers (AC and KE) to register and further describe their capabilities to offer manufacturing services (i.e. Production of EBs) as well as broadcast their capacities at given times in terms of machine availability and raw materials. The Provider's planning department (AC) and EMS group (KE) logs into the T4M Marketplace and navigates to the "Provider's Area", where they can input the necessary general information via the supplier wizard. T4M ensures that all mandatory fields are completed before submission. The supplier wizard requests specific details regarding the company, Additionally, the supplier signs a Non-Disclosure Agreement (NDA) to maintain the confidentiality of any information obtained from the consumer during the provision of manufacturing services. To provide its services, T4M requires access to information related to the manufacturing capabilities of its providers. This information may include sensitive details such as technical specifications of the manufacturing capabilities such as, production planning, and material usage history and inventory. In particular for VN1 providers share information relevant to (a) EBs they can produce, (b) EBs' BoM – to be used later to automatically create value network configurations, (c) Historical and current material availabilities and (d) historical and current production schedules as well as (e) historical and current forecasted ETAs for shipments of EBs. As part of T4M's onboarding procedure, the provider's IT department enables the provision of the respective data to the T4M system as well as facilitates the interactions of the factory systems (e.g. ERP) with the T4M infrastructure. This involves detailing the relevant datasets and defining the conditions under which they can be used.

Similarly, Consumers (AR and AB) register and provide information relevant to their organization. T4M is committed to ensuring secure and trustworthy access to all information in accordance with the defined usage conditions. Once the provider has completed the onboarding procedure, T4M validates and finalises the onboarding process. From this point onwards, the provider becomes eligible to receive new manufacturing services requests. The T4M Marketplace should support the procurement process of manufacturing services, including ad hoc configuration of matching value chains and follow up.

Phase#2. Request Manufacturing Service

Having providers onboard the T4M, the consumers can request their need for a new manufacturing service (i.e. Production of EBs). On that account, when a consumer (AR or AB), having completed the Consumer onboarding process, registers a request for a manufacturing service (EBs for Washing machines or EBs for Cooking Appliances) in T4M, the consumer's Planning Department (PD) proceeds to sign in to the T4M Marketplace and through a consumer's request wizard they can log a new manufacturing service request (MS Request) for the production of new EBs. The request wizard prompts the PD to provide specific data that describes product (EBs) and process (if any e.g. allocation mixture between providers) requirements tailored to the selected manufacturing service. This includes details such as EBs Identifiers, quantity of EBs to be produced, and applicable selection criteria (multiple criteria may apply e.g. mixture of providers, time of delivery). T4M ensures that all mandatory information is completed before the MS Request can be submitted. T4M guarantees a secure exchange of information provided by the consumer, ensuring compliance with

intellectual property rights (IPR) and privacy regulations. The MS Request is stored in the consumers' request history for future reference.

Phase#3. Share matching supply chain configurations

Upon submission of the MS Request, T4M automatically: (i) extracts product and process requirements from the provided details (i.e. the EBs requested for production); (ii) identifies a group of registered providers that match the requirements, considering their capabilities (ability to produce the specific EBs) and the existence of available manufacturing resources, alongside all specified criteria; and (iii) presents the selected providers ranked according to the criteria. These providers are shown as supply chain configurations, which may consist of one or multiple providers based on the matching results (e.g. All EBs from a single provider, or EBs from mix of providers). Each configuration's information is segmented into lines corresponding to the requested manufacturing services for EBs production, displayed in a scoreboard format with additional details and filtering options to assist the Consumers' PD in making an informed decision. In VN1 in particular once the PD of a Consumer has issued a request, T4M examines the EBs requested and identifies the providers that can produce them based on the EBs' decomposition into materials, potential Production and Delivery schedules and Contractual parameters (given by the Consumer), whilst taking under consideration all other current production processes of other customer factories withing the T4M scope.

Phase#4. Request manufacturing service

PD compares, using the scoreboard included in T4M, the proposed supply chain configurations (mixture of Providers for the production of EBs), selects the most suitable one(s) and submits a request for manufacturing service offer (MS Request for Production) in each Provider separately but automated. Before submitting the MS Request for Production T4M checks that the mandatory information has been completed. T4M ensures a trustworthy exchange of the information provided by the consumer and stores it. PD can decide to launch only one request for quotation or several ones in parallel through T4M. It notifies the request to the providers involved in the selected supply chain configurations. Each MS Request for Quotation is linked to the MS Request that has generated it.

Phase#5. Share Manufacturing Service Offer

When the Planning Department of the Providers (PD or EMS) within the selected supply chain(s) receive the notification, they log into the "Provider's Area" to access the pending "MS Request for Production." These requests are grouped by MS Request. Providers can view the information provided by the consumer in the MS Request, including EBs to be produced, time of delivery and remaining provider selection criteria (such as suitable manufacturing resources to be used to produce the EBs, estimated time of delivery based on logistics historical information).

Using this information, the PDs create a firm manufacturing service response that covers the assigned services (Manufacturing of EBs for Cooking appliances or Washing machines) by accepting the request or in the case production cannot be met Requests for an "Order revision". T4M provides an "response wizard" to facilitate this process, including a response line for each required service. It performs a sanity check on the MS offer before submission, ensuring that all mandatory fields are completed and that delivery dates are consistent. At this stage, the MS Response is linked to the initial MS Request.

Phase#6. Release Manufacturing Service Order – T4M Contract

For each MS Response submitted, T4M notifies the manufacturing service consumer (AR and AB) that a new response is ready for review. The PD can then review the response and choose to accept it, reject it, or start an Order revision process. Once the PD accepts a manufacturing service response, T4M converts it into a manufacturing service order (MS Order), which includes all the manufacturing services as complete supply chains (EBs to be produced by the given Provider(s)). T4M then notifies the involved MaaS Provider(s) that the MS Order has been released and informs the remaining potential suppliers that their responses have been rejected.

Phase#7. Monitoring & Follow up Manufacturing Service Order

When the PDs(s) of the selected providers acknowledge receipt of the MS Order, they generate an internal work order for the corresponding purchase order and integrate it into their production planning using their internal legacy systems (ERP, MS Excel etc.). Each internal work order must be linked to the originating MS Order. From this point, T4M assists in monitoring the status continuously, of the manufacturing service order, tracks updates, and notifies the MaaS Consumer (this adheres to the production of EBs from materials within AC and KE). If there are deviations, then the Providers' representative must inform the T4M so that the consumer can change the requested quantity or wait for a smaller quantity of delivered product, which may be covered in a subsequent order or provide the system with a new Request for Manufacturing Service (Phase #4) now with specific number of EBs and fixed deadline for delivery.

T4M provides a wizard that allows the Provider to request revisions by entering information relevant to Orders that can be fulfilled within the SO. Upon a new Request for revision, the Consumers' PD is informed and can proceed to either revise their order with the provider or utilize T4M system to direct the remaining Parts of the Order to a new Request for manufacturing service and the active MS Order is updated.

When products are shipped to the final consumer, the supplier's PD updates the order line status and provides shipment details. T4M monitors the process for potential deviations. If deviations occur (e.g., extended deadlines, potential penalties), T4M initiates, if necessary, an internal incident linked to the (ongoing) MS Order. The goal is to propose a reconfiguration of the supply chain, which should also be validated by the corresponding provider(s).

The PD or the provider evaluates the incident and implements mitigation actions (e.g., rescheduling the work order linked to the service order line). If the incident cannot be resolved, T4M updates the MS Order information (setting the status to "incident" and including incident details) and notifies the consumer. When the PD receives a deviation notification (i.e., MS Order status set to "incident"), they access T4M, evaluate potential alternatives (if any), and select the best option (e.g., do nothing, alter the demand order, cancel the order with/without penalty, and select a new provider).

Phase#8. Validation & Close Manufacturing Service Order

Once the order is received and its contents are validated by the quality responsible, the PD of the Consumers side, can close the manufacturing service order. T4M will then notify the supplier in the selected supply chain configuration.

Phase#9. Share Performance

Both the consumer (PD) and the providers (PD and EMS Group) can provide feedback on the procurement process. The PD can report on the manufacturing service, including details on compliance with specifications and delivery dates towards the creation of forecasts for future MS Orders.

3.2 User Roles

In this section we present the involved user roles, for the four organizations i.e., roles that participate in the procurement and production processes.

Table 1: VN1 User Roles

ID	Organization	Role	Description	T4M Role
VN1UR1	AC	Planning Department (PD)	The Planning Department is responsible for interacting with all Customers and receive their orders and produce them. Additionally, its role is to interact with the logistics third parties to provide shipment ETAs	• Register the organization o Provide Capabilities (EBs that provider manufactures, BoM per EB) o Provide Capacities (Material Inventory Data, Stock Inventory data, Production Schedule, Shipment ETAs) • Respond to MS Request (Providers) • Accept Manufacturing Service Order (T4M Contract) • Request Update of MS Order • Update T4M on Manufacturing Service Order Evolution • Provide Feedback on completed MS Orders • Provide Forecasts (and Updates) of Orders • Validate and Close Manufacturing Service Order
VN1UR2	KE	EMS Group (Production & Logistics)	The EMS group is composed of the production and the logistics divisions. Production is responsible for interacting with all Customers and receive their orders and produce them. The logistics division's role is to arrange for the shipment of EBs to consumers and inform T4M for EBs ETA.	• Register the organization o Provide Capabilities (EBs that provider manufactures, BoM per EB) o Provide Capacities (Material Inventory Data, Stock Inventory data, Production Schedule, Shipment ETAs)

ID	Organi-zation	Role	Description	T4M Role
				• Respond to MS Request (Providers) • Accept Manufacturing Service Order (T4M Contract) • Request Update of MS Order • Update T4M on Manufacturing Service Order Evolution • Provide Feedback on completed MS Orders • Provide Forecasts (and Updates) of Orders • Validate and Close Manufacturing Service Order
VN1UR3	AR	Planning Department (PD)	The Planning Department is responsible to order the EBs in a manner that meets the contractual requirements of Ordering from different suppliers	• Register the organization • Provide Forecasts (and Updates) of Orders • Provide details on Orders of EBs • Select Supply chain configurations on Orders • Accept Manufacturing Service Order (T4M Contract) • Update Manufacturing Service Orders • Validate and Close Manufacturing Service Order
VN1UR4	AB	Planning Department (PD)	The Planning Department is responsible to order the EBs in a manner that meets the contractual requirements of Ordering from different suppliers	• Register the organization • Provide Forecasts (and Updates) of Orders • Provide details on Orders of EBs • Select Supply chain configurations on Orders • Accept Manufacturing Service Order (T4M Contract) • Update Manufacturing Service Orders • Validate and Close Manufacturing Service Order
VN1UR5	All	IT Dept (IT)	Each providers' / suppliers' internal IT department	• Facilitate interoperability of Partner's systems with T4M

3.3 T4M Marketplace Information Exchange

In this section we describe the information and the documents that will be used in the context of this value network that relate to the ordering of EBs and their production from varied material that the T4M will utilize in order to facilitate a seamless interaction between the Providers and the Consumers.

Table 2: VN1 Exchanged information

ID	Name	Description	Included Data	Partner involvement
VN1IM1	EBs	The Electronic Boards that are requested to be produced under a Service Order	• Name • EB Identifier (Provider) • EB Identifier (Consumer) • Characteristics (Dimensions, Weight etc.)	AC, KE, AR, AB
VN1IM2	BoM per EB	Each EB has a respective Bill of Materials (BoM) which are utilized in its production	• ID of Material • Name of Material • Quantities • EB Identifier (Provider) • EB Identifier (Consumer)	AC, KE
VN1IM3	Provider's general info	Provider's typical info about the company and services available	• General info of the company: Name, address, contact details. • Catalogue of manufacturing services to be offered (EBs that can be produced)	AC, KE
VN1IM4	Consumer's general Info	Consumers' typical info about the company	• General info of the company: Name, address, contact details.	AR, AB
VN1IM5	Provider's matching and follow up information	Provider's capability, capacity and manufacturing execution information	• Capability: VN1IM3 – Catalogue of EBs + VN1IM1 • Ability to produce EBs: Information on the production planning for EBs • Ability to produce EBs: Forecast of ETAs of EBs	AC, KE
VN1IM6	MS Request	Enquiry for the production of new EBs	• EB(s) Identifier • Quantity of EBs • Selection criteria	AR, AB
VN1IM7	Supply chain configuration	Matching supply chain configurations	• Ordered list of providers able to perform the requested service • Matchmaking information generated by T4M	T4M

ID	Name	Description	Included Data	Partner involvement
VN1IMP8	MS Request for Quotation	Enquiry to providers of EBs	• General information on the MS Request information • Matchmaking information generated by T4M. • Addition information to support the response process (if relevant)	AR, AB, T4M
VN1IMP9	MS Response	Manufacturing service response submitted by each supply chain configuration	• General information on the MS Request information • Status of the MS Offer (Released, Rejected, Accepted) • Provider general information • Availability to produce EBs • Delivery Date • Validity period • Special conditions	AC, KE, AR, AB, T4M
VN1IMP10	MS Order	Manufacturing service order with agreed conditions including an order line per manufacturing service	• General order information • Information per offer line (linked to specific manufacturing service) • Oreder status (Released, Planned, Produced, Shipped, Delivered, Closed, Incidence)	AC, KE, AR, AB, T4M
VN1IMP11	Performance of procurement process	Performance of the manufacturing service providers based on Quality-of-Service criteria.	• Updated Forecasts • QoS criteria Response	AC, KE, AR, AB, T4M

3.4 User Stories

In this section, we present the user stories (USs) that were collected and validated through various rounds of VN1 interviews and workshops with the industrial partners of this VN. All user stories include the involved user roles, their objective, and the reason why this objective is important.

Table 3: VN1 User Stories

ID	Description
Onboarding Process	
US1.1	As a Provider / Consumer I want to register my organization to enable manufacturing as a Service Production of EBs

ID	Description
US1.2	As T4M, I want the Consumer's/Provider's IT representative to provide me secure access to sensitive information about capabilities and capacities, so that I can make them available on an as-a-service basis
US1.3	As T4M, I want to check the information that the Provider / Consumer has entered, so that I can validate the completeness of the Provider's/Consumer's registration phase and inform the Provider's PD that they are eligible to receive new manufacturing service requests and the Consumer's PD that they are eligible to request new manufacturing service requests.
Manufacturing as a Service Request – T4M Contract	
US1.4	As the Planning Department of Consumer (AR, AB) I want a step-by-step wizard which prompts for input data describing product (EBs) and process requirements (e.g. delivery time) because I want to place a request for a manufacturing service.
US1.5	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 PD
US1.6	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.
US1.7	As the Provider Planning Department (AC)/EMS Group (KE) I want a step-by-step wizard to automatically assess my capability to produce EBs by the provided material inventory, production planning schedules and forecasted ETAs to enable me to review requests and release manufacturing services quotations to Customers for EBs I can produce and deliver.
US1.8	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
Service Order (Contract) Monitoring and Follow up	
US1.9	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.
US1.10	As a Consumer / Provider 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.
US1.11	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.

3.5 User Requirements

In this section, we present the user requirements in the form of use cases (UCs) where the pre-conditions, UC steps, and post-conditions are defined. This is followed by a UML diagram where the involved actors (human roles or systems) are depicted. These UCs are extracted from the USs presented in the previous section.

US1.1

Description: *As a Provider/Consumer, I want to register/sign up my organization to enable manufacturing as a Service Production of EBs. This user story is based on a single use case i.e. UC1.1: Register Value Network Organization*

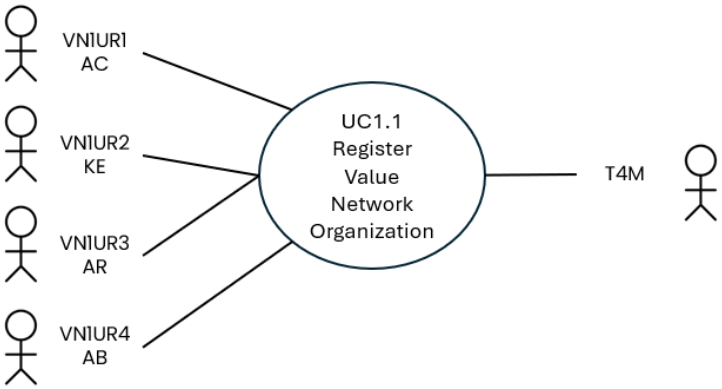


Figure 4: VN1 User case diagram for US1.1

Table 4: VN1 Description of UC1.1

UC1.1	Register Value Network Organization
Brief Description	This use case outlines the actions taken to register a new company as a Provider / Consumer by providing a company's general information (Provider / Consumer) and provisioning the initial capabilities (Provider) upon which the manufacturing services that are being offered on a manufacturing as a service will be based.
Initiation	On demand when a new company wants to be registered in T4M as a Provider / Consumer.
Primary Actors	1. User: PD (AR, AB, AC), EMS-Group (KE)
	2. System: T4M Marketplace (T4M)
Pre-conditions	AR, AB, AC, KE must be logged in.
Post-conditions	1. Company is registered as Provider / Consumer
	2. Provider Capabilities are available to the T4M system
	3. Provider Current Capacities are available to the T4M system
	4. Granting access process is initiated
Basic Flow	1. Provider PD(AC) – EMS Group (KE) accesses the "Company's Area to register the company as a Provider
	2. T4M provides a wizard to include the information required to get specific details (VN1IM2, VN1IM3, VN1IM5) about the company and the acknowledgment of an NDA to ensure the confidentiality of any information from the other value network partners to which it may have access.
	3. Provider completes the required information and submits
	4. T4M checks that the mandatory information has been completed.
Alternative Flow(s)	At step 2 if the logged in user is a Consumer the information at VN1IM4 are requested only
	At step 2, If user has not completed all the mandatory information T4M informs that he/she needs to complete all required information before submitting it.
	If a system error occurs, a message is displayed to user explaining what went wrong

US1.2

Description: *As T4M, I want the consumer's / provider's IT representative to provide me secure access to sensitive information about capabilities and capacities, so that I can make them available on an as-a-service basis. This User Story is based on a single use case i.e. UC1.2 Grant Data Access.*

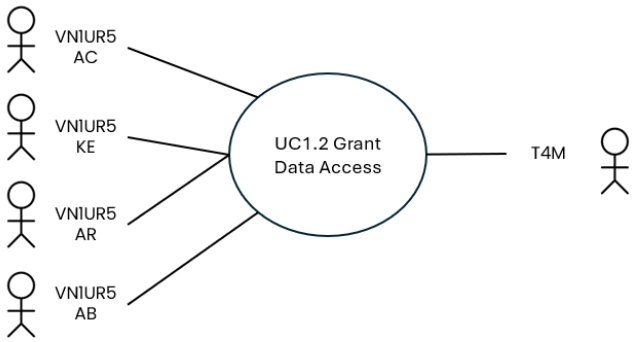


Figure 5: VN1 User case diagram for US1.2

Table 5: VN1 Description of UC1.2

UC1.2	Grant Access Data
Brief Description	This use case outlines the actions taken to complete the onboarding process by granting T4M access to relevant manufacturing-related information in accordance with specific data usage policies.
Initiation	On demand when a new provider / consumer wants to grant access to a specific set of datasets and describe usage policies.
Primary Actors	1. User: IT Responsible of Providers and Consumers VN1UR5
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. IT Responsible must have required access rights
	2. Required capabilities and capacities are available.
Post-conditions	1. Access to required capabilities and capacities is granted
	2. Data usage policies are defined
	3. Acknowledgement of process completion.
Basic Flow	1. IT Responsible describes, through the available user interface, the shared datasets including the required information related to manufacturing capacity and capability according to the T4M onboarding conditions
	2. IT Responsible defines through the available UI the usage conditions of the exposed information according to companies' internal data governance policies
	3. IT Responsible acknowledges that the process has been completed
Alternative Flow(s)	At step 1 if the logged in user is a Consumer access to the information at VN1IM4 is requested
	If a system error occurs, a message is displayed to user explaining what went wrong

US1.3

Description: *As T4M, I want to check the information that the Provider / Consumer has entered, so that I can validate the completeness of the Provider's / Consumer's registration phase and inform the Provider's PD that they are eligible to receive new manufacturing service requests and the Consumer's PD that they are eligible to request new manufacturing service requests.*

This user story is based on a main use case i.e., UC.1.3. Validate onboarding process.

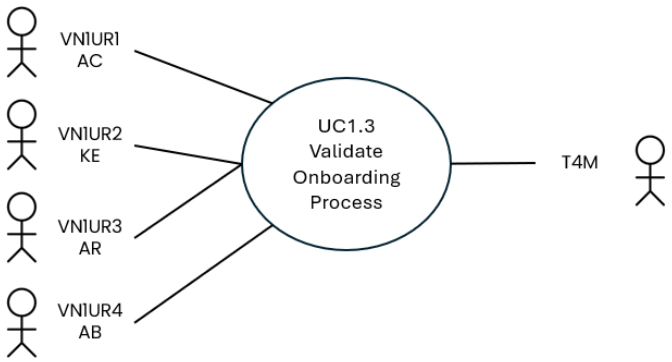


Figure 6: VN1 User case diagram for US1.3

Table 6: VN1 Description of UC1.3

UC1.3	Validate Onboarding Process
Brief Description	This use case outlines the actions required to complete the onboarding process, making the provider eligible to receive new manufacturing service requests and the consumer eligible to request new manufacturing service requests.
Initiation	On event when access granting process is completed
Primary Actors	1. User: PD of Providers and Consumers (PD)
	2. System: T4M Marketplace (T4M)
Pre-conditions	Access granted is completed.
Post-conditions	1. Provider onboarding is completed
	2. Consumer onboarding is completed
	3. Provider is eligible to receive new manufacturing service requests
	4. Consumer is eligible to request new manufacturing service requests.
Basic Flow	1. T4M validates the process by checking that the required data have been accessible according to the requirements defined in the onboarding procedure
	2. T4M notifies PD that the company has finalized the onboarding process successfully
Alternative Flow(s)	If a system error occurs, a message is displayed to user explaining what went wrong

US1.4

Description: *As the Planning Department of Consumer (AR, AB) I want a step-by-step wizard which prompts for input data describing product (EBs) and process requirements (e.g. delivery time) because I want to place a request for a manufacturing service.*

This user story is based on a main use case: i.e., UC1.4 Request manufacturing service.

Figure 7: VN1 User case diagram for US1.4

Table 7: VN1 Description of UC1.4

UC1.4	Request Manufacturing Service
Brief Description	This use case outlines the actions taken to create and submit a new request for the production of EBs for which the consumer seeks to find matching providers complying with its specific need and selection criteria.
Initiation	On demand when a Consumer needs a new manufacturing service of EBs.
Primary Actors	1. User: PD (AR, AB)
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. PD (AR or AB) must be logged in
	2. Product (EBs) and Process specification are available

UC1.4	Request Manufacturing Service
Post-conditions	PD submits a request for a manufacturing service
Basic Flow	1. PD selects the Manufacturing Service Request option in Consumer GUI
	2. T4M providers a list of available manufacturing services (EBs per logged in User)
	3. PD identifies the manufacturing service(s) needed
	4. T4M provides a wizard to include the information required to describe the selected manufacturing service
	5. PD creates the manufacturing service request (MS Request) by providing the required information
	6. T4M checks that mandatory information have been completed
	7. T4M stores the MS Request in the MaaS Consumer's request history so it can be consulted at any time
Alternative Flow(s)	At step 7 if PD has not completed all mandatory information T4M informs PD for the requirement to complete all information prior to creating an MS Request
	If a system error occurs T4M informs PD for what went wrong

US1.5

Description: *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 PD.*

This user story is based on two use cases:

- UC1.5 Extract manufacturing service requirements.
- UC1.6. Identify and display matching supply chain configurations.

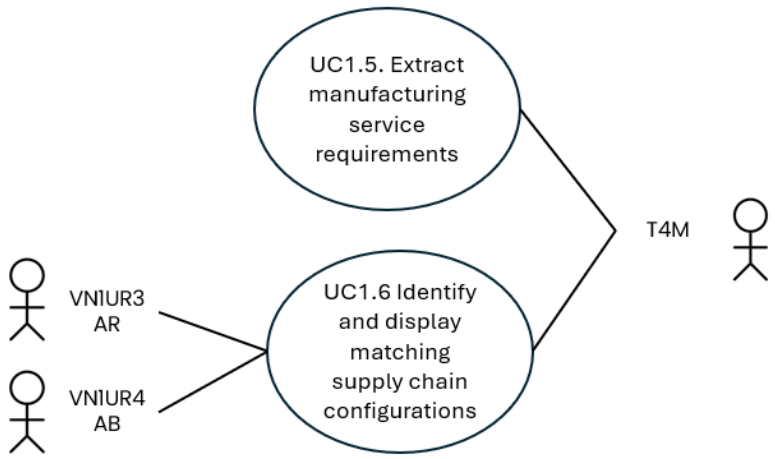


Figure 8: VN1 Use Case diagram for US1.5

Table 8: VN1 Description of UC1.5

UC1.5	Extract Manufacturing Service Requirements
Brief Description	This use case outlines the actions taken to extract product and process requirements from the information collected in the manufacturing service request.
Initiation	On event when a new manufacturing service request is submitted.
Primary Actors	System: T4M Marketplace (T4M)

UC1.5	Extract Manufacturing Service Requirements
Pre-conditions	A complete manufacturing service request is submitted.
Post-conditions	1. Product requirements are identified.
	2. Process requirements are identified.
Basic Flow	T4M extracts, automatically, product and process requirements from the information collected in the manufacturing service request based on the specific manufacturing service request.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 9: VN1 Description of UC1.6

UC1.6	Identify and display matching supply chain configurations
Brief Description	This use case outlines the actions taken to identify the matching providers to compose the supply chains, and to rank them (as proposed by the appropriate T4M service) by considering their capabilities along with all the selection criteria.
Initiation	On event when the product and process requirements have been extracted
Primary Actors	1. System: T4M Marketplace (T4M)
	2. User: PD (AR, AB)
Pre-conditions	1. Product requirements are identified
	2. Process requirements are identified
	3. Providers are already registered in T4M
	4. Use Case 1.8 been completed.
Post-conditions	1. Matching supply chain(s) are identified.
	2. Matching supply chain(s) are ranked according to selection criteria.
	3. Matching supply chain(s) are displayed in the scoreboard.
Basic Flow	1. T4M identifies the providers with manufacturing resources that support the product and process requirements (capability)
	2. T4M identifies, from the previous selection, the providers with appropriate manufacturing resources that are available in the requested period of time (UC1.8).
	3. T4M optimizes and combines them in ranked supply chain configurations according to the specific selection criteria
	4. T4M displays the selected matching supply chain configurations. The information of each supply chain configuration is broken down in as many lines as requested manufacturing services and displayed in a scoreboard including both additional information and filtering capabilities to support informed selection.
Alternative Flow(s)	At step 4, If there are no matching supply chain configurations a message is displayed.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US1.6

Description: *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.*

This user story is based on a main use case i.e., UC1.7. Request manufacturing service quotation.

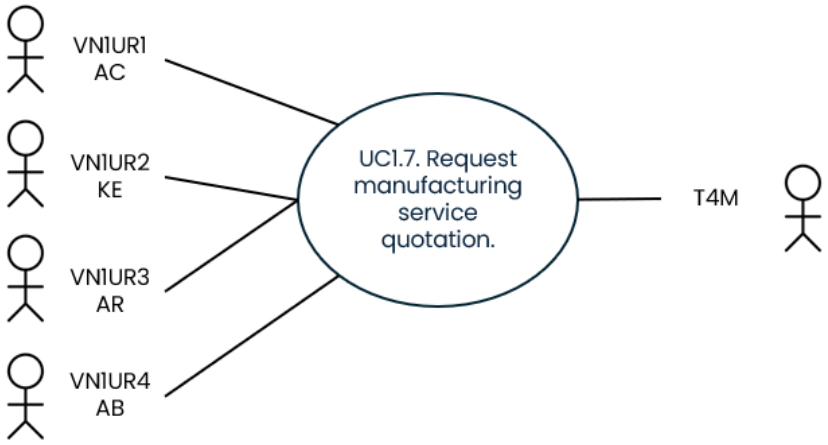


Figure 9: VN1 Use Case diagram for US1.6

Table 10: VN1 Description of UC1.7

UC1.7	Request manufacturing service quotation
Brief Description	This use case outlines the actions taken to evaluate the proposed matching supply chain configurations, select the most suitable ones and submit quotation requests.
Initiation	On demand when the matching supply chain configurations are displayed.
Primary Actors	1. Users: PD (AR, AB), PD(AC), EMS (KE)
	2. System: T4M Marketplace (T4M)
Pre-conditions	PD must be logged in
Post-conditions	1. Matching supply chain configurations displayed in the scoreboard.
	2. Matching supply chain configurations evaluated.
Basic Flow	1. PD compares matching supply chain configurations displayed in the scoreboard considering all the provided information and taking advantage of the filtering capabilities.
	2. PD includes, if relevant, additional information or upload additional documents.
	3. PD submits a request for manufacturing service quotation to gather pricing information (including both manufacturing and delivery costs)
	4. T4M checks that the mandatory information has been completed
	5. T4M notifies the providers involved in the selected supply chain configuration that a new request for quotation is available.
Alternative Flow(s)	At step 4, If the PD has not completed all the mandatory information T4M informs PD that he/she needs to have all required information validated before submitting the MS Quotation Request.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US1.7

Description: *As the Provider Planning Department (AC)/EMS Group (KE) I want a step-by-step wizard to automatically assess my capability to produce EBs based on my capacity, production planning schedules and forecasted ETAs to enable me to review requests and release manufacturing services quotations to Customers for EBs I can produce and deliver.*

This user story is based on two use cases:

1. UC1.8 Upload Production Schedule, Inventory and forecasted ETAs
2. UC1.9 Share manufacturing service offer

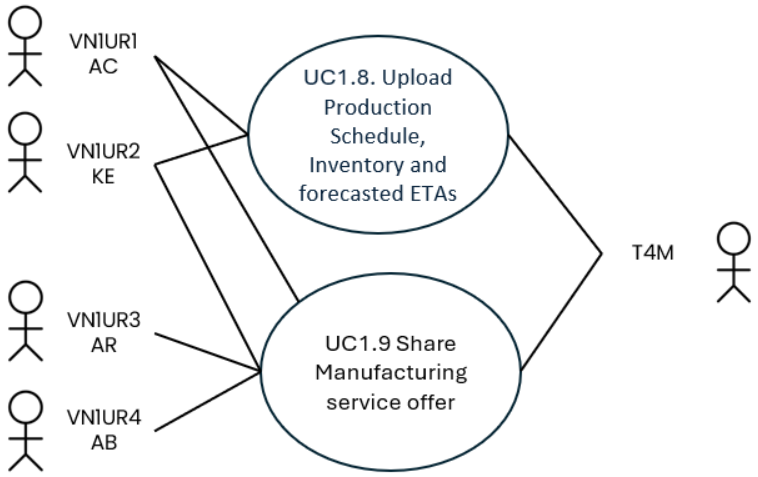


Figure 10: VN1 Use Case diagram for US1.7

Table 11: VN1 Description of UC1.8

UC1.8	Upload Production Schedule, Inventory and forecasted ETAs
Brief Description	This use case outlines the actions taken from the PD(AC) and EMS Group (KE) to introduce to the T4M system their material inventory, production schedule and forecasted ETAs in order to identify per supply chain configuration their ability to produce the requested EBs relevant to the product and process requirements put forth in the MS request.
Initiation	On demand when the manufacturing service quotation request has been submitted and notified.
Primary Actors	1. Users: Sales PD(AC) or EMS Group (KE)
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. AC, KE must be logged in
	2. Manufacturing service quotation requests are available.
Post-conditions	1. Manufacturing service offer can initiate.
Basic Flow	1. AC, KE access providers area
	2. T4M presents a list for introducing the current production schedule and Inventory
	3. AC, KE Uploads to the system the production schedule
	4. AC, KE Uploads to the system the current inventory
	5. T4M presents a list of the supply chain configurations that can be produced given the production schedule and material availability
Alternative Flow(s)	At step 5, If no supply chain configurations can be identified, KE, AC are informed.
	If a system error occurs, a message is displayed to the user explaining what went wrong

Table 12: VN1 Description of UC1.9

UC1.9	Share manufacturing service offer
Brief Description	This use case outlines the actions taken to evaluate the proposed matching supply chains, select the most suitable ones and submit quotation requests.
Initiation	On demand when the manufacturing service quotation request has been submitted and notified.

UC1.9	Share manufacturing service offer
Primary Actors	1. Users: PD (AR, AB), PD (AC), EMS Group (KE)
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. Users must be logged in
	2. UC1.8 must be successfully completed
	3. Manufacturing service quotation requests are available
Post-conditions	Manufacturing service offer is submitted.
Basic Flow	1. AC, KE involved in the selected supply chain configuration accesses the pending MS Request for Quotation in the Providers area that are displayed (grouped by MS Request).
	2. AC, KE selects a quotation request from the list.
	3. T4M displays an offer wizard including: • general information provided by the customer in the MS Request along with the criteria that have been considered for the selection as suitable provider, the information of other members in the supply chain and their position in relation to them, as well as any relevant additional information generated by T4M during the matchmaking process (e.g., EBs etc.). • an offer line per required manufacturing service, identifying the target provider, to include the price (broken down in manufacturing service, shipping and taxes as separated concepts), the confirmed delivery date (based on the providers ETA forecast, the validity period of the offer (i.e., timeframe during which the offer is considered valid), and any additional observation to specify special conditions or restrictions.
	4. KE, AC analyses the general information displayed in the offer wizard, completes the information requested (price breakdown, delivery date, the validity period, and potential comments) in the assigned offer line(s) and submits the provider manufacturing service offer.
	5. T4M checks that the mandatory information has been completed in all the offer lines, as well as the consistency of the delivery dates of the involved manufacturing services.
	6. T4M stores the MS Offer linked to the MS Quotation Request that has triggered it so it can be consulted at any time.
	7. T4M notifies the consumer (AR, AB) that a new manufacturing service offer is available.
Alternative Flow(s)	At step 5, if KE, AC involved in the selected supply chain configuration have not completed all the mandatory information T4M informs the user that he/she needs to have all required information validated before submitting the MS Quotation Request.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US1.8

Description: *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.*

This user story is based on three use cases.

1. UC1.10 Review manufacturing service offer conditions.
2. UC1.11 Negotiate/clarify manufacturing service offer conditions.
3. UC1.12 Release manufacturing service order conditions.

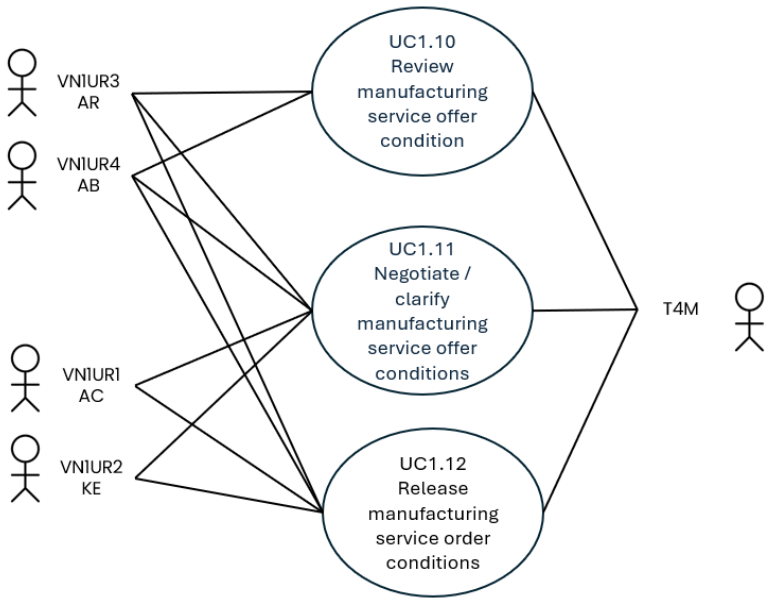


Figure 11: VN1 Use Case diagram for US1.8

Table 13: VN1 Description of UC1.10

UC1.10	Review manufacturing service offer conditions
Brief Description	This use case outlines the actions taken to evaluate the proposed manufacturing service offers and decide whether to initiate a negotiation/clarification phase.
Initiation	On demand when a manufacturing service offer has been submitted and notified.
Primary Actors	1. Users: AR, AB
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. AR, AB must be logged in
	2. Manufacturing service offer is available
Post-conditions	1. Manufacturing service offer is evaluated.
	2. Negotiation/clarification process is open (if needed).
Basic Flow	1. AR, AB accesses the pending manufacturing service offers in the Consumer area.
	2. AR, AB selects a manufacturing service offer from the list.
	3. T4M displays the information related to the selected offer, broken down in offer lines which include the price (broken down in manufacturing service, shipping and taxes as separated concepts), the confirmed delivery date, the validity period of the offer (i.e., timeframe during which the offer is considered valid), and any additional observation to specify special conditions or restrictions.
	4. AR, AB evaluates each offer line and decides whether or not to open a negotiation/clarification process.
Alternative Flow(s)	At step 4, AR, AB can agree on what has been proposed and decide not to open a negotiation/clarification process.
	At step 4, AR, AB can decide that it is not worth to open a negotiation/clarification process and reject the offer.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 14: VN2 Description of UC1.11

UC1.11	Negotiate/clarify manufacturing service offer conditions
Brief Description	This use case outlines the actions taken to during a negotiation/clarification process.
Initiation	On demand when a negotiation/clarification process is open.
Primary Actors	1. Users: AR, AB, AC, KE
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. AR, AB, AC, KE must be logged in
	2. Manufacturing service offer is available
	3. AR, AB has decided to open a negotiation/ clarification process
Post-conditions	1. Manufacturing service offer conditions are updated (if needed).
	2. Negotiation/clarification process is closed (either when an agreement is reached or when no agreement can be reached).
Basic Flow	1. AR, AB selects an offer line and initiates a negotiation/clarification process by requesting clarifications/modifications and submitting them.
	2. T4M notifies the involved providers(s) that a negotiation/clarification process has been opened.
	3. AR, AB and AC, KE take advantage of T4M to exchange information till an agreement is reached.
	4. AR, AB updates manufacturing service offer conditions if needed.
Alternative Flow(s)	At step 3, AR, AB can reject the offer if no agreement can be reached.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 15: VN1 Description of UC1.12

UC1.12	Release manufacturing service order conditions
Brief Description	This use case outlines the actions taken to release an order.
Initiation	On demand when the manufacturing service offer conditions acceptable.
Primary Actors	1. Users: PD (AR, AB, AC), EMS Group (KE)
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. AR, AB, KE, AC must be logged in
	2. Manufacturing service offer is available
	3. Manufacturing service order conditions are clear and acceptable.
Post-conditions	1. Manufacturing service offer is accepted
	2. Manufacturing service order is generated.
Basic Flow	1. PD (AR, AB) checks final conditions and accepts manufacturing service offer.
	2. T4M transforms the manufacturing service offer in a manufacturing service order (MS Order), including as many order lines as included manufacturing services.
	3. T4M stores the manufacturing service order.
	4. T4M updates the status of unsuccessful the manufacturing service offers (status=rejected).
	5. T4M notifies the providers involved in the selected offer that a manufacturing service order has been released.
	6. T4M notifies the providers whose offers have not been selected that they have been rejected.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

US1.9

Description: *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.*

This user story is based on a main use case i.e., UC1.13 Follow up manufacturing service order that includes an alternative workflow if a potential deviation is detected.

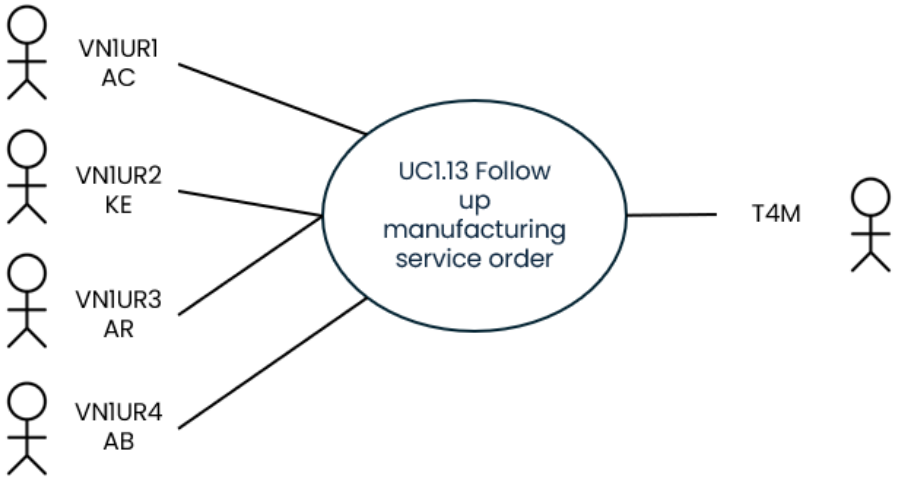


Figure 12: VN1 Use Case diagram for US1.9

Table 16: VN1 Description of UC1.13

UC1.13	Follow up manufacturing service order
Brief Description	This use case outlines the actions taken to follow-up a service order. In particular it deals with execution of the service order as well as potential deviations of production / delivery on the producers' side.
Initiation	On event when the manufacturing service order has been released.
Primary Actors	1. Users: PD (AB, AR) and PD (AC) and EMS Group (KE)
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. Users must be logged in
	2. Manufacturing service order has been released
Post-conditions	1. Manufacturing service order status is updated.
Basic Flow	1. PD (AC) / EMS Group (KE) of the selected provider acknowledge reception
	2. PD (AC) / EMS Group (KE) generates an internal work order for the related MS Order.
	3. T4M follows the status of the manufacturing service order line and identifies updates (order: planned, produced).
	4. T4M notifies manufacturing service order updates (order line: planned, produced) to consumer.
	5. When the EBs are shipped, to the final consumer, the PD (AC) or EMS Group (KE) updates the status of the related order line (order line: shipped) and provides shipment information through the order wizard.

UC1.13	Follow up manufacturing service order
	6. T4M notifies manufacturing service order update (order: shipped)
	7. T4M notifies manufacturing service order updates (order: shipped) to consumer.
Alternative Flow(s)	At step 3 PD(AC) or EMS Group (KE) can update T4M with information on deviations in an order. If this is the case: 1. T4M assesses. the impact of such deviation (e.g. increased deadline, potential penalties.) 2. T4M opens an internal incidence linked to the manufacturing service order. 3. The PD (AC) or EMS Group (KE) assesses the potential incidence and launches mitigation actions (e.g. re-schedule the work order linked to the service order) to close it. If the incidence cannot be solved and remains open. 4. T4M updates manufacturing service order (i.e., updates status=incidence and includes the incidence information) 5. T4M notifies the consumer -PD (AR or AB) about the incidence. 6. The consumer's PD accesses T4M to evaluate the incidence and decide on potential alternatives (e.g., decide to keep the order as is, cancel the order with no penalty and select a new provider).
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US1.10

Description: *As a PD (AR, AB) 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.*

This user story is based on one main use case: UC1.14 Manufacturing service order finalisation.

Figure 13: VN1 Use Case diagram for US1.10

Table 17: VN1 Description of UC1.14

UC1.14	Manufacturing service order finalisation
Brief Description	This use case outlines the actions taken to close a manufacturing service order after it has been validated by the consumer.
Initiation	On demand when the manufacturing service order has been validated.
Primary Actors	1. Users: PD (AR, AB)
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. PD must be logged in
	2. Manufacturing service order has been delivered to the consumer.
Post-conditions	1. Manufacturing service order status is updated.
	2. Providers (AC, KE) involved in the manufacturing service order are notified.
	1. When the EBs are received, and validated PD (AR, AB) closes the manufacturing service

UC1.14	Manufacturing service order finalisation
Basic Flow	order (order: closed).
	2. T4M updates the status of the final order (order: completed).
	3. T4M notifies all the providers involved in the selected supply chain configuration that the order has been closed.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

US1.12

Description: *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.*

This user story is based on two main use cases.

- UC1.14. Share manufacturing service performance

Figure 14: VN1 Use Case diagram for US1.11

Table 18: VN1 Description of UC1.15

UC1.15	Share manufacturing service performance
Brief Description	This use case outlines the actions taken to report on the performance of the manufacturing service and rate the involved providers based on quality-of-service criteria.
Initiation	On demand when the manufacturing service has been validated and closed.
Primary Actors	1. Users: PD (AR, AB) and PD(AC) / EMS Group (KE)
	2. System: T4M Marketplace (T4M)
Pre-conditions	1. PD (AR, AB), PD(AC), EMS Group (KE) must be logged in
	2. Manufacturing service has been validated and closed.
Post-conditions	1. Providers are rated based on quality-of-service criteria.
	2. Providers rating is updated.
Basic Flow	1. PR reports on the manufacturing service by, including info on compliance with specification, and delivery date.
	2. T4M (re) calculates providers rating.
	3. T4M notifies the involved PD(s) of AC / EMS Group (KE) on the availability of new performance reports.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

3.6 Existing systems and related user stories

In this section, we describe the existing systems that are involved in the development of the different inquiries of VN1. As a core aspect of T4M functionality, enabling automated import/export of the Information Models' (IMs) contents to the different systems of the Consumers and the Providers is essential. The following systems were identified as necessary for developing the IMs after conducting related Engineering work.

Table 19: VN1 Existing systems and related User Stories

VN Users	Existing System	Related US	Connection Type	Data Imported to T4M
AC	• SAP (Production Planning) • Macro (Excel) (Procurement) • MES Optimus: (Manufacturing) • SAP (Logistics)		Data Transfer (.xls)	• BOM for EB's • Raw Material Inventory • Dispatch Data for EB Orders
AR	• SAP (Procurement) • SAP (Production Planning) • SAP (Logistics EB's received)		Data Transfer(.xls)	• Requirement for EB's • Date of EB's received •
AB	• SAP (Procurement) • SAP (Production Planning) • SAP (Logistics EB's received)		Data Transfer (.xls)	• Requirement for EB's • Date of EB's received
KE	• Oracle ERP and Macro (Excel) (Production Planning) • Oracle ERP (Real time data)		Data Transfer(.xls)	• BOM for EB's • Raw Material Inventory • Dispatch Data for EB Orders

3.7 KPIs, Calculation Methods and Baselines

In this section we describe the KPIs that will be used to assess the T4M tangible (measurable) impact of the VN1 pilot context. The assessment involves the comparison of the as-is and the to-be situation, an approach that it will be applied to all Value Networks. This comparison is based on specific KPIs which are defined in terms of (a) the objective that is required, (b) the baseline of the KPI (as-is situation) and (c) the target value of the KPI after the T4M implementation.

VN1-ARC:

1. **KPI1: Production Capacity Utilization Rate**
    - Definition: The ratio of actual production capacity usage divided by design capacity.
    - Calculation description and function: The design capacity of the system is registered in the Production Planning module of SAP and actual monthly production is calculated.
    - Related Data: Monthly Production Plans and confirmed production quantity
    - Availability of data: Available as Excel file (.xls)
    - Baseline: 88%,

- Goal: To increase the production capacity of utilization rate to 92% by the end of the project.

2. **KPI2: Order fulfilment rate (OTIF)**
    - Definition: This KPI measures the percentage of customer orders delivered on time and in full. It reflects the ability to efficiently fulfil customer orders by meeting their delivery deadlines and providing all the correct items.
    - Calculation description and function: The OTIF is calculated by dividing the number of orders delivered on time and in full by the total number of customer orders placed during a specific period (e.g., day, week, month).
    - Related Data: Number of orders placed, number of orders delivered on time and in full, order fulfilment lead times, inventory levels, shipping information.
    - Availability of data: There is no order management system, the orders are shared by e-mails, there is SAP WMS system that gives inventory levels and shipping information.
    - Baseline: 82.91%
    - Goal: To increase the Order fulfilment rate to 95% by optimize inventory management and implement order management system

3. **KPI3: Material Stocks**
    - Definition: This KPI measures the company's inventory coverage ratio, expressed in months, to fulfil current production needs.
    - Calculation description and function: Material Stock Coverage (in months) = Current Stock Quantity / Average Monthly Consumption
    - Related Data: Current stock quantity, average monthly consumption.
    - Availability of data: The data can be extracted from the SAP ERP system.
    - Baseline: 2.7,
    - Goal: To reduce the Material stocks to 1 by improving demand forecasting

4. **KPI4: Finished product stock keeping**
    - Definition: Finished product stock keeping is the average duration that finished products remain in inventory before being shipped.
    - Calculation description and function: Stock Keeping Days = Total Number of Products / Total Days Products are in Stock
    - Related Data:
    - Availability of data
    - Baseline: 3 days

VN1-KAREL:

1. **KPI1: Production Capacity Utilization Rate**
    - Definition: The ratio of actual production capacity usage divided by design capacity.
    - Calculation description and function: The design capacity of the system is registered in Production Planning module of Oracle and actual monthly production is calculated.
    - Related Data: Monthly Production Plans and confirmed production quantity
    - Availability of data: Available as Excel file (.xls)

- Baseline: 77%
- Goal: To increase the production capacity of utilization rate to 90% by the end of the project.

2. **KPI2: Order fulfilment rate (OTIF)**
    - Definition: This KPI measures the percentage of customer orders delivered on time and in full. It reflects your ability to efficiently fulfil customer orders by meeting their delivery deadlines and providing all the correct items.
    - Calculation description and function: The OTIF is calculated by dividing the number of orders delivered on time and in full by the total number of customer orders placed during a specific period (e.g., day, week, month).
    - Related Data: Number of orders placed, number of orders delivered on time and in full, order fulfilment lead times, inventory levels, shipping information.
    - Availability of data: There is no order management system, the orders is shared by e-mails, there is an Oracle system that gives inventory levels and shipping information.
    - Baseline: 36% (This data can be revised)
    - Goal: To increase the Order fulfilment rate to 90% by optimizing inventory management and implementing order management system

3. **KPI3: Material Stocks**
    - Definition: This KPI measures the company's inventory coverage ratio, expressed in months, to fulfil current production needs.
    - Calculation description and function: Material Stock Coverage (in months) = Current Stock Quantity / Average Monthly Consumption
    - Related Data: Current stock quantity, average monthly consumption.
    - Availability of data: The data can be extracted from Oracle ERP system.
    - Baseline: 2.7
    - Goal: To reduce the Material stocks to 1 by improving demand forecasting,

4. **KPI4: Finished product stock keeping**
    - Definition: Finished product stock keeping is the average duration that finished products remain in inventory before being shipped.
    - Calculation description and function:
    - Stock Keeping Days= Total Number of Products/Total Days Products are in Stock
    - Related Data: Current stock quantity.
    - Availability of data: There is no order management system, the orders is shared by e-mails, there is Oracle system that gives inventory levels and shipping information.
    - Baseline: 3 days
    - Goal: To reduce the Material stocks to 1 by improving demand forecasting

VN1-AB:

1. **KPI1: Finished product stock keeping**
    - Definition: This KPI measures approximately how many days of stocks of product the facility has in order to make production
    - Calculation description and function: Stock Day = (Current Product Stock/Average Product Consumption) *30

- Related Data: Monthly product consumption and product stocks
- Availability of data: The data can be extracted from SAP ERP
- Baseline: 15 days
- Goal: To reduce the finished product stock keeping to 7 days by the end of the project.

VN1-AR:

2. **KPI1: Finished product stock keeping**
    - Definition: This KPI estimates the number of days' worth of product inventory the facility has available for production.
    - Calculation description and function: Stock Day = (Current Product Stock/Average Product Consumption) / 30
    - Related Data: Monthly product consumption and product stocks
    - Availability of data: The data can be extracted from the SAP ERP
    - Baseline: 15 days
    - Goal: To reduce the finished product stock keeping to 7 days' worth

4 Value Network 2: Requirements and KPIs

4.1 Description

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* (see Figure 15 below). 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.

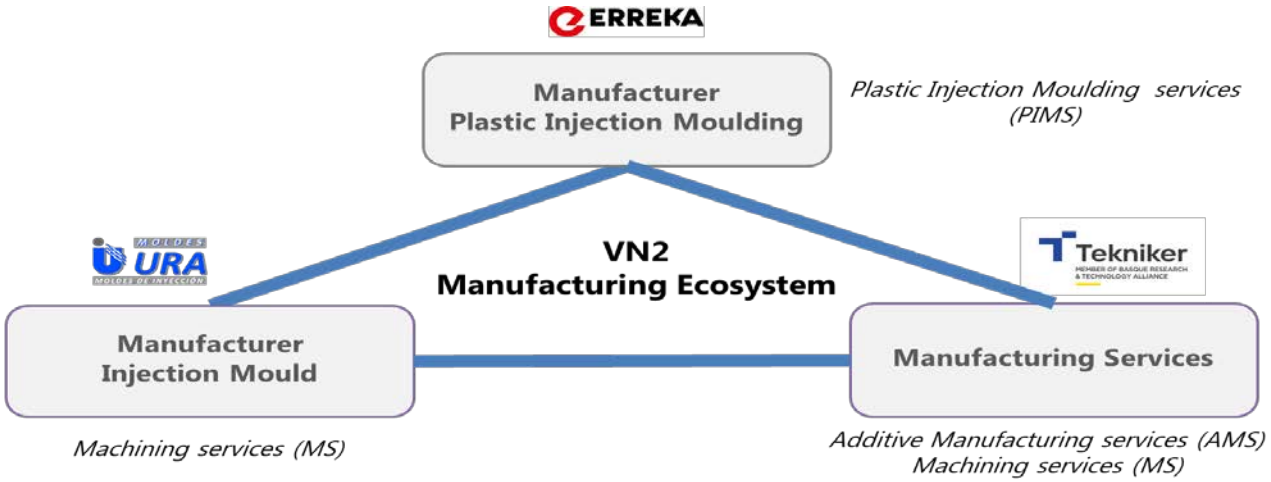


Figure 15: VN2 Ecosystem

ERREKA Plastics 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).

Moldes 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. Moldes 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 (MS). Available machining resources involve CNC Milling machines, CNC machining centres, CNC turning machines, and EDM machines.

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).

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.

4.1.1.1 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 in terms of machine hours and raw materials as well as providing information on manufacturing execution.

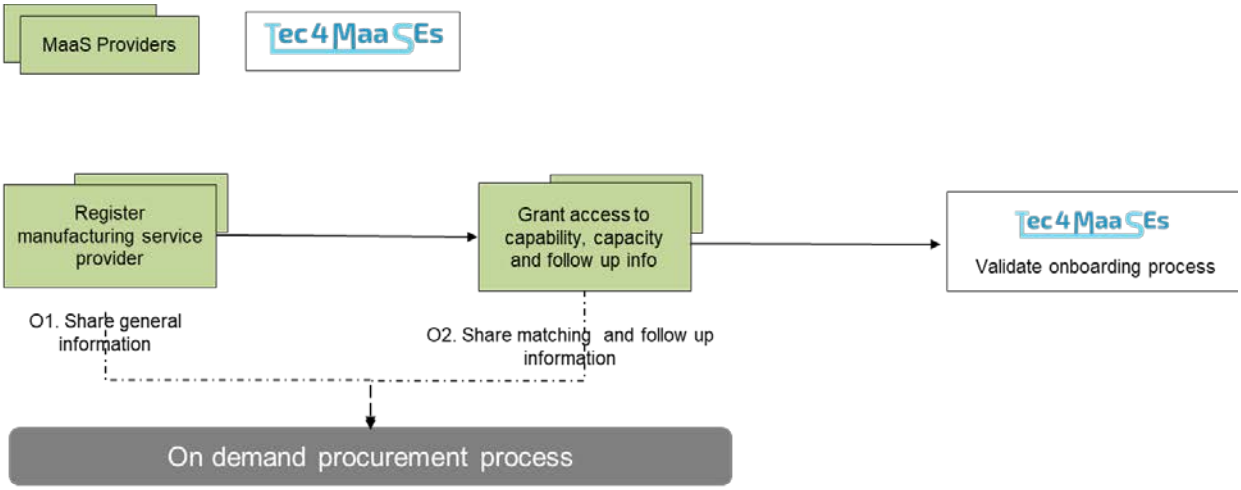


Figure 16: VN2 Providers' onboarding process and information flows

The main phases of the providers' onboarding process are described below.

Phase#1: Register manufacturing service provider

The provider's sales responsible (SR) logs into the T4M Marketplace and accesses the *"Provider's Area"* where they can enter the required general information using the provider wizard. T4M ensures that all mandatory fields are completed before submission. The provider wizard requests specific details about the company, the catalogue of manufacturing services (by selecting them from the list of services supported by T4M), and the list of shipping countries. Furthermore, the provider signs an NDA to ensure the confidentiality of any information from the consumer to which it may have access during the provision of the manufacturing services.

Phase#2: Grant data access

To provide its services, T4M needs access to the providers' information related to the manufacturing resources supporting these services. This information may include sensitive details such as technical

specifications of the manufacturing resources, production planning, or resource usage history. A minimum set of information to describe both capabilities and capacities (i.e., availability) and to support the follow up of the manufacturing service should be made available according to the T4M onboarding procedure. The specific information required to describe the capabilities of the available manufacturing resources will vary depending on the type of manufacturing resource.

Following T4M's onboarding procedure, the provider's IT representative grants access to the required information by describing it and defining usage conditions, through the available user interface.

This information can be updated by the IT representative at any time. T4M will ensure secure and trustworthy access to all the information in accordance with the defined usage conditions.

Phase#3: Validate onboarding process.

Once the provider has completed the onboarding procedure, T4M validates the onboarding process by checking that the required data have been accessible according to the requirements defined in the onboarding procedure and finalises. From this point onwards, the provider becomes eligible to receive new manufacturing services requests.

4.1.1.2 On demand procurement process.

The T4M Marketplace should support the procurement process of manufacturing services, including ad hoc configuration of matching value chains and follow up.

Figure 17 describes an ideal on demand procurement process from manufacturing service request to manufacturing servicer order completion.

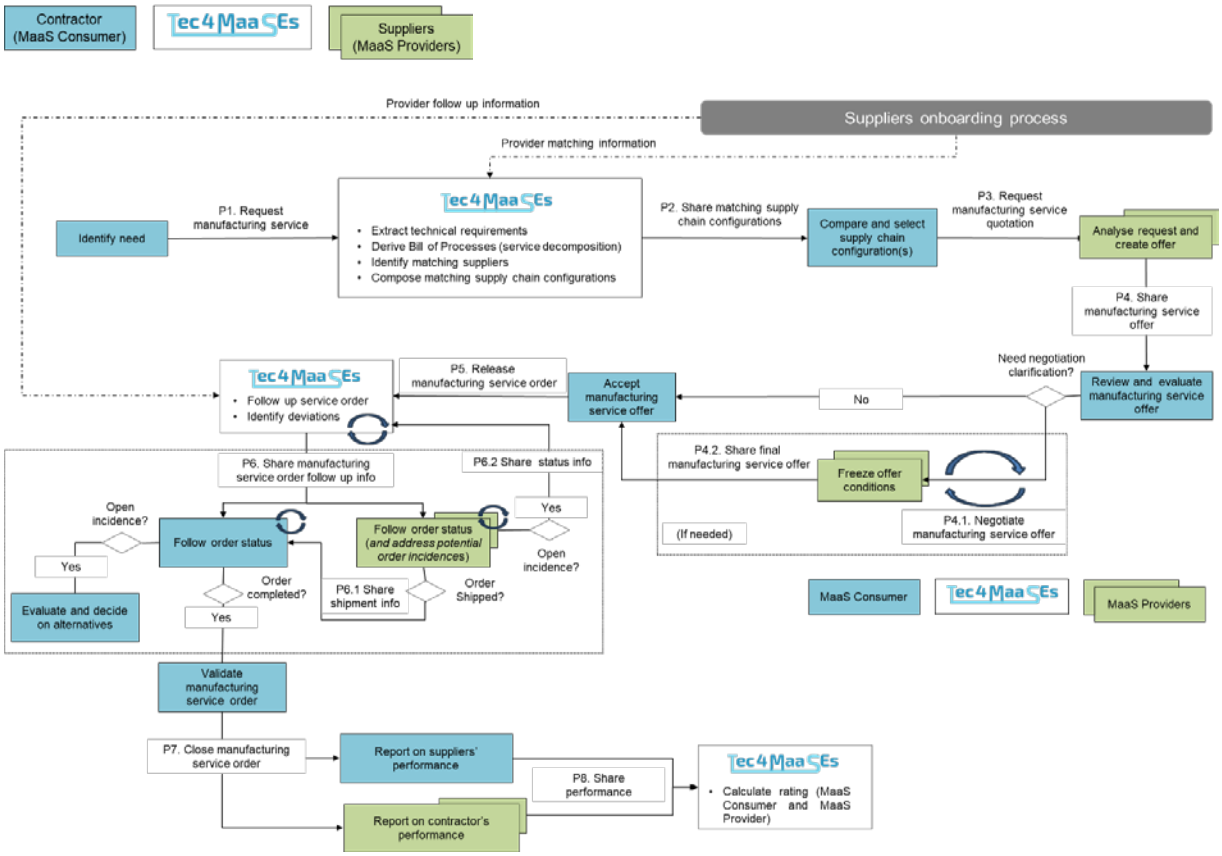


Figure 17: VN2 Phases of T4M Marketplace. On demand procurement process

The main phases of on-demand manufacturing service procurement are described below.

Phase#1: Request manufacturing service

When a consumer has a request for a manufacturing service (AMS, MachS or PIMS) registered in T4M, the consumer's procurement responsible (PR) signs into the T4M Marketplace, accesses the consumer's request wizard and logs a manufacturing service request (MS Request). The request wizard prompts for specific data to describe product and process requirements based on the selected manufacturing service (e.g. AMS, MachS, PIMS), including material details, the number of parts to be produced, and applicable selection criteria (multiple criteria may apply, refer to ANNEX B, for detailed selection criteria). Any eligible provider specifies availability dates as part of the selection criteria. Before broadcasting the MS Request T4M crosschecks the mandatory information and verifies its completeness. T4M should guarantee the trustworthy exchange of the information provided by the consumer to comply with data sovereignty directives.

This phase depends on the specific manufacturing service, as the required information to describe product and process requirements varies.

Phase#2: Share matching supply chain configurations.

Once the MS Request is submitted, T4M automatically: (i) extracts product and process requirements from the provided information; (ii) identifies a set of matching providers, from those already registered, considering their capabilities (against the identified requirements) and capacity of the available manufacturing resources along with all the selection criteria; and (iii) displays the set of selected suitable providers ranked based on the identified selection criteria and represented as supply chain configurations, that can contain one or multiple providers (depending on the results of the matching process). The information of each supply chain configuration is broken down in as many lines as requested manufacturing services and is displayed in a scoreboard including both additional information and filtering capabilities to allow PR to achieve an informed selection.

Service composition is a core component of the phase in order to select the optimal service combinations from the candidate set of each subtask based on the Quality of Service (QoS) which includes dimensions like time, cost, reliability and capability with respect to the functional and non-functional requirements of the requested service. Nonetheless, at this phase, price is not included in the selection criteria since it does not depend only on the providers' internal costs (i.e., manufacturing and personnel costs) but also on other aspects like the programmers' expertise to select the most appropriate manufacturing strategy or the specific characteristics of the manufacturing resources.

This phase is manufacturing service dependent as the capability matching conditions vary according to the requested manufacturing service.

Phase3: Request service quotation

PR compares, using the scoreboard included in T4M, the proposed supply chain configurations, selects the most suitable one(s) and submits a request for manufacturing service quotation (MS Request for Quotation), to gather pricing information (including both manufacturing and delivery costs). When submitting the quotation request PR has the option to include additional information or upload additional documents. Before submitting the MS Request for Quotation T4M checks that the mandatory information has been completed. T4M ensures a trustworthy exchange of the information provided by the consumer and stores it.

PR can decide to launch only one request for quotation or several ones in parallel through T4M. T4M notifies the request to the manufacturers involved in the selected supply chain configurations. Each MS Request for Quotation is linked to the MS Request that has generated it.

Phase#4: Share manufacturing service offer

When the sales representative(s) (SRs) of the Providers within the selected supply chain(s) receive the notification, they log in to the "Provider's Area" in order to gain access to the pending "MS Request for Quotation". These are grouped by MS Request (in case a provider is involved in several requests for quotation linked to the same MS Request). SR(s) can get the information provided by the consumer in the MS Request along with the selection criteria, and (if applicable) the information of other members within the supply chain, their position in relation to them, as well as any relevant additional information generated by T4M during the matchmaking process (e.g., suitable manufacturing resources, part weight and volume, etc.).

Based on the available information, the SR(s) generates a manufacturing service offer that covers the manufacturing services assigned to them (i.e., AMS, MS, PIMS). To generate the MS Offer T4M provides an "offer wizard" which includes an offer line per required manufacturing service. Each SR offer includes multiple fields along with "price" (decomposed in manufacturing service, shipping and taxes), "delivery date" and "offer's validity period". Additional fields on special conditions and/or restrictions could be added depending on the individual case. Finally, T4M performs a sanity check of the MS offer prior to its submission, by confirming the mandatory fields as well as the consistency of the delivery dates. At this stage the MS Offer is linked to the MS Quotation Request that has initiated it.

Phase#5: Release manufacturing service order

For each MS Offer submitted, T4M notifies the manufacturing service consumer that a new offer (MS Offer) is ready for review. From that moment onwards, PR can review the offer and accept it, reject it, or otherwise initiate a negotiation/clarification process. PR can initiate a negotiation/clarification process per offer (i.e., linked to a specific manufacturing service). If consensus is reached, and there are changes in any of the initial conditions, the agreement should be updated accordingly by the provider's sales representative. PR closes the negotiation/clarification process either when an agreement is reached or when no agreement can be reached.

If the PR has requested more than one offer, they are eligible to accept any of the already submitted offers without waiting for the pending ones. On the other hand, there may a requirement based on which the PR might consider all submitted offers within some fixed deadline.

Once PR accepts a manufacturing service offer T4M transforms it on a manufacturing service order (MS Order), and notifies the involved MaaS Provider(s) that the MS Order has been released, as well as the rest of the potential providers that their offers have been rejected.

Phase#6: Follow up manufacturing service order.

When SR(s) of the selected providers acknowledge reception, they should then generate an internal work order for the related MS Order and include it in their respective production planning (using their internal legacy systems). Each internal work order should be linked to the MS Order that generated it. From this point onwards T4M follows the status of the manufacturing service order, identifies updates and provides notifications to the MaaS Consumer, as well as to the next provider in the supply chain.

When products are shipped, either to the next provider in the supply chain or to the final consumer, the SR of the provider in charge updates the status of the related order and provides shipment information. When the next provider in the supply chain receives the products, they acknowledge reception.

T4M monitors the process for potential deviations. The impact of such deviations (e.g. increased deadline) is assessed and when deemed necessary an internal incidence linked to the MS Order is initiated. Its aim is to propose (if possible) potential alternatives which should be validated by the corresponding provider(s).

The SR or the provider assesses the potential incidence and launches mitigation actions (e.g. re-schedule the work order linked to the service order). If the incidence cannot be resolved, T4M updates the MS Order information (i.e., updates status=incidence and includes the incidence details) and notifies the next provider(s) in the supply chain (if any) and the consumer.

When PR gets the notification for a deviation (i.e., MS Order status=incidence) he/she accesses T4M, evaluates potential alternatives (if any) and selects the best option (e.g., do nothing, cancel the order with/without penalty and select a new provider).

Phase#7: Validate manufacturing service order

When the order is received, and its content is validated by the quality responsible, PR can close the manufacturing service order. T4M then notifies all the providers involved in the selected supply chain configuration.

Phase#8: Share performance

Both the consumer (PR) and the providers (SRs) can report on the performance of the procurement process. On the one hand the PR can report on the manufacturing service (e.g. by including info compliance with specification, and delivery date). On the other hand, even if payment is managed outside the scope of T4M, following internal company's procedures the SR(s) can report on the payment performance (e.g. meeting stipulated deadlines). T4M considers this information to calculate the rating of both the consumers and providers and notifies them on the availability of new performance reports.

Our discussion up to now perceived T4M from two different perspectives, namely the Provider's and Consumer's perspective. The Use Cases described in the above sections can be clustered analogously in BC1 and BC2 which include three and two business sub cases respectively. This structure is illustrated schematically in Figure 18.

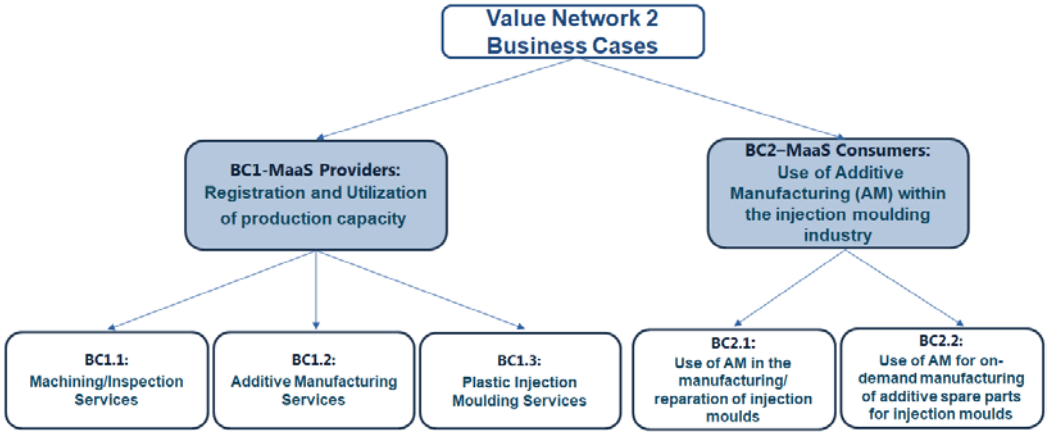


Figure 18: VN2 Schematic Representation of VN2 business cases.

BC1 - MaaS Providers: Registration and utilisation of (regular or under used) production capacity

Business Case 1 (BC1) consists of three sub-cases, all related to the registration of a supplier as a provider within T4M. The primary objective is to make *intensive use of production capacity by offering it as a service to third parties*. The main distinction among these sub-cases lies in the *domain of the offered service*.

Adopting a business model based on sharing (regular or under used) manufacturing capacity can provide several benefits to manufacturing service providers. These include generating revenue from assets without additional investment, recovering fixed costs associated with maintaining manufacturing facilities, accessing

new markets and customers, and increasing sustainability by maximizing the utilization of existing infrastructure and minimizing waste.

T4M should provide technologies to enable a MaaS Marketplace able to improve visibility of manufacturing services providers (i.e., allowing to register both the manufacturing capabilities and capacities) to optimise capacity use through collaborative business models and incorporate data sovereignty aspects to ensure privacy and trusted data sharing.

However, introducing a new business model to share manufacturing capacity involves building new value networks to make this capacity available to third parties, which can require significant effort *(Challenge 1.1)*. Additionally, providing production capacity on a MaaS basis introduces privacy issues due to the exchange of sensitive data, such as production planning and internal costs, which must be properly addressed *(Challenge 1.2)*. These business challenges are summarized in Table 20.

Table 20: VN2 BC1 Challenges summary

Challenge		
#	**Name**	**Description**
Challenge 1.1	Visibility of available manufacturing services	Providing means to share manufacturing capacity within a network of potential consumers.
Challenge 1.2	Privacy management	Addressing privacy issues due to the exchange of sensitive data (e.g., production planning, internal costs, etc.) by supporting trustworthy data sharing considering data sovereignty aspects.

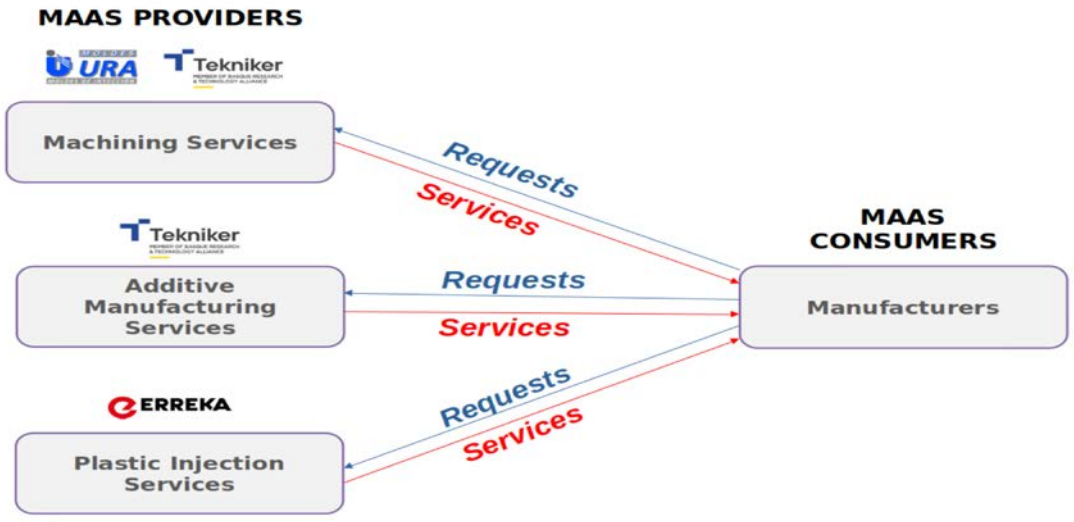


Figure 19: VN2 BC1 involved partners and roles

BC1 focuses on the process of provider registration within the T4M marketplace. In this scenario, three types of services can be registered: *Machining Services (MachS), Additive Manufacturing Services (AMS) and Plastic Injection Moulding Services (PIMS)*. Within the VN2 context, MachS can be registered by both Moldes URA and Tekniker, AMS is exclusively offered by Tekniker, while PIMS is offered solely by ERREKA. BC2 (see Figure 18) examines the on-demand procurement process. In BC1, we use a simulated demand model to represent multiple requests from MaaS consumers to examine MaaS transformation of the Business model for manufacturing requests either on demand (core business) or for sharing capacity. Consider for instance the case where MaaS providers are exploring the potential of introducing a new business model to share some

of their underutilized machining resources with third-party companies, following a MaaS approach. While, in some cases, providing manufacturing services to third parties is not their core business, they aim to increase their visibility as potential providers of manufacturing services and to build new value chains incorporating manufacturing services consumers.

The consumers in this scenario are manufacturers or providers of industrial services involving additive manufacturing and/or machining or plastic injection moulding. They sometimes need to outsource services to third parties due to insufficient capacity, lack of specific capabilities, or the inability to handle a peak in demand.

In the proposed scenario, providers leverage the T4M Marketplace to integrate a network of manufacturing services. This network spans multiple consumers (with simulated production sites) and takes advantage of T4M Marketplace, to support the entire procurement process, from the initial service request to its final delivery.

It should be noticed that in the case of AMS, MachS the specific data describing product and process requirements in Phase 1 (i.e., Request Manufacturing Service) are embedded in the CAD file and 2D drawings and what varies, depending on the manufacturing service, is the information to be extracted from them. In the case of PIMS specific data describing process requirements should be provided by describing the specific process parameters.

BC2 - MaaS Consumers: Use of Additive Manufacturing (AM) within the injection moulding industry

Plastic injection moulding, a manufacturing process that produces parts by injecting molten material into a mould, requires a new mould for each new part. Typically, these moulds are owned by the OEM.

Overall, BC2 focuses on the on-demand procurement phase, showcasing the application of T4M technologies that enable flexible (re)configuration of value networks in response to disruptive events. In this context, the disruptive event is the introduction of a new technology, specifically additive manufacturing, through servitisation in the plastic injection moulding sector to avoid high investment costs, either on infrastructure or on expensive spare part inventories.

Production stoppages in the plastic injection moulding sector are costly, leading to several implications: (1) it is a sector that requires short lead times from providers, (2) spare parts (i.e., inserts) are stored to anticipate any possible failure, representing a significant investment, even if the real demand for spare parts is low, as failures should not occur often. Moulds are composed of structural components such as clamping plates, support plates, ejecting systems as well as cavity inserts that define the shape of the part (see Figure 20).

When a new part needs to be injected, moulds are requested by the producer of plastic injected parts from a mould manufacturer. The mould user provides the CAD files of the part to be injected, and the mould manufacturer must sign a non-disclosure agreement (NDA).

The mould manufacturer then follows an iterative product development process, involving both design and manufacturing stages, in collaboration with the mould user to create the injection mould and all its components (e.g., structural components, inserts, etc.). Once the mould is completed, it is sent to the mould user along with its CAD files. The moulds are tested to ensure proper functionality. Occasionally, some components that need to be repairs or replacements, including the cavity insert itself or structural parts such as clamping plates, support plates and ejecting systems.

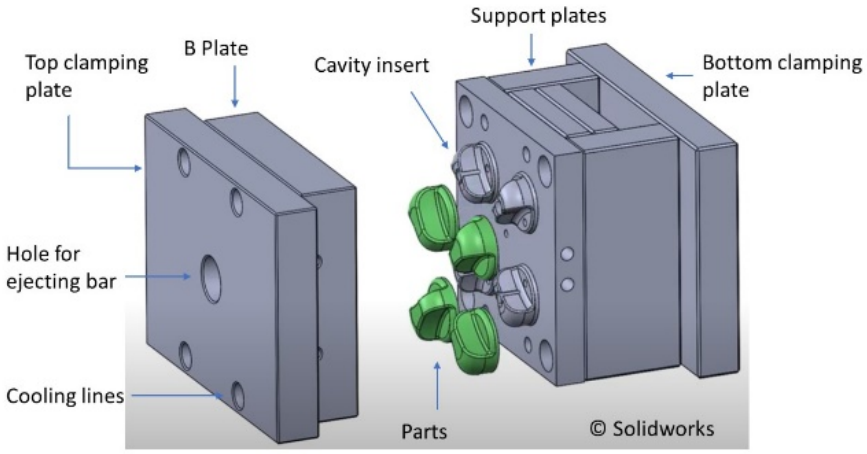


Figure 20: VN2 Mould components

The use of AM is becoming increasingly common for producing certain parts of the moulds, particularly cavity inserts and some metal structural components. AM is favoured for its ability to produce highly complex parts that are easily customized to specific user requirements, as well as its flexibility and cost-effectiveness. This cost-effectiveness is especially significant when large amounts of material need to be removed, as AM reduces material waste, and in the production of unitary or low quantities of parts. However, the use of AM services to produce metal structural pats or inserts require additional finishing processes. These include machining to meet the geometrical and surface requirements imposed by the customer (since the part produced by AM is larger than the final product), and coating to enhance technical properties. Within the framework of the envisaged finishing processes is primarily machining. The proposed solution should provide a complete manufacturing service, including both additive manufacturing and the necessary machining services *(Challenge 2.1)*.

In addition, building and configuring new value networks including partners providing AM services involves identifying new potential providers, contacting them to learn about their capabilities and availability and selecting suitable ones based on specific needs (e.g. changing selection or quality of service criteria, changing manufacturing capacity of the potential providers, etc.). Achieving this process through traditional means (e.g., web searches, telephone, email, etc.) can be time consuming and error-prone (*Challenge 2.2*).

Furthermore, using AM and related machining processes on a MaaS basis can introduce new challenges such as privacy issues due to IPR management (*Challenge 2.3*), or loss of control of the overall manufacturing process (*Challenge 2.4*). These challenges, succinctly summarized in Table 21, are addressed within the T4M marketplace. This is exemplified through two business sub-cases, BC2.1 and BC2.2 (see Figure 21).

Table 21: VN2 BC2 Challenges summary

Challenge		
#	**Name**	**Description**
Challenge 2.1	*Provision of complete service*	*Provide a complete manufacturing service that includes additive manufacturing, and when necessary, the required machining services.*
Challenge 2.2	*Flexible (re)configuration of new value networks*	*(Re-)configuring ad-hoc value networks to include partners offering new manufacturing services (e.g., AM and related services) based on specific needs such as changing selection or quality of service criteria and adjusting the manufacturing*

Challenge		
#	Name	Description
		capacity of potential providers.
Challenge 2.3	*Privacy management*	*Addressing privacy issues due to IPR management by supporting trustworthy data sharing considering data sovereignty aspects.*
Challenge 2.4	*Preventing loss of control*	*Preventing loss of control by offering explainable configuration propositions and incorporating follow-up capabilities for the requested manufacturing service.*

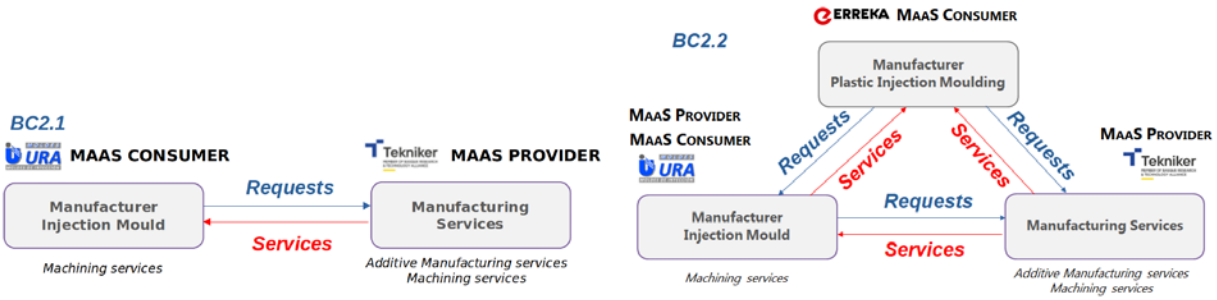


Figure 21: VN2 Schematic representation of partner's roles in BC2.1 and BC2.2.

BC2.1 Use of AM in the manufacturing/reparation of injection moulds

Two members of VN2, Moldes URA and Tekniker, are involved in showcasing BC2.1 (see Figure 21, BC2.1). Moldes URA, a manufacturer of injection moulds, opts to use additive manufacturing (AM) for producing some structural metal components or inserts of the mould during the design of a new mould or the repair of an existing one. This decision is driven by the complexity of the components or the need to subtract a significant amount of material, aiming to speed up time to market and reduce costs.

Since Moldes URA only has machining capabilities, it requires a specialized provider for the additive manufacturing process (i.e., AMS without related services, excluding the finishing process to be machined in-house). As the designer, Moldes URA possesses the CAD and 2D drawings that include product specifications from which process requirements can be derived. Currently, building new supply chains involving AMS providers necessitates identifying, contacting, selecting, and involving them through traditional means (e.g., web searches, telephone, email), which is effort-intensive and prone to errors.

Tekniker provides industrial services that include both additive manufacturing and machining. We assume that Tekniker has registered in T4M Marketplace as a provider of both AM and machining services (see BC1). Moldes URA leverages T4M to streamline the procurement process for the required AMS and monitor it from the service request to the delivery of the manufactured parts.

Regarding the "on-demand procurement process" (see Section 4.1.1.2, Figure 18) the specific data describing product and process requirements in Phase 1 (i.e., Request Manufacturing Service) are embedded in the CAD file and 2D drawings. In Phase 2 (i.e., Identify and Share Matching Supply Chain Configuration), T4M should extract this information to identify suitable additive manufacturing resource candidates.

BC2.2 - Use of AM in on-demand manufacturing of additive spare parts for injection moulds

Three members of VN2—ERREKA, Moldes URA, and Tekniker—are involved in showcasing BC2.2 (see Figure 18, BC2.2). When ERREKA, a manufacturer specialised in plastic injection moulding and an injection mould

user, needs to replace deteriorating injection mould spare parts such as cavity inserts, it orders new ones, on demand, to minimize the need for expensive spare part inventories. These parts are produced using additive manufacturing due to the reduced number of requested parts, and/or their complexity or the substantial material removal required.

In this case, a comprehensive service that includes both Additive Manufacturing Service (AMS) and Machining Services (MachS) is necessary to meet part specifications. ERREKA possesses the CAD and 2D drawings that include product specifications from which product and process requirements can be derived, provided by the mould manufacturer along with the mould. Currently, to build new supply chains involving AMS and MachS providers, ERREKA must identify, contact, select, and coordinate them through traditional means (e.g., web searches, telephone, email), which is effort-intensive and prone to errors. Note that Moldes URA has no additive manufacturing capabilities but can provide machining services to finish the cavity insert. On the other hand, TEKNIKER provides industrial services involving both AMS and MachS.

Moldes URA is assumed to be registered in the T4M Marketplace as a provider of machining services (see BC1.1) while TEKNIKER is registered as a provider of both additive manufacturing and machining services (BC1.1 & BC1.2). Finally, ERREKA takes advantage of T4M to support the procurement of the required AM and MachS and follow it up from the service request to the delivery of the manufactured parts.

In this case it may happen that the whole service can be provided by a single provider (I.e., providing both AMS and MachS) or multiple providers need to be involved (e.g. one providing AMS and another providing MachS). In case multiple providers are involved material flows between providers need to be considered.

Regarding the “on-demand procurement process” (see Section 4.1.1.2, Figure 18) the specific data describing product and process requirements in Phase 1 (i.e., Request Manufacturing Service) are embedded in the CAD file and 2D drawings. In Phase 2 (i.e., Identify and Share Matching Supply Chain Configuration), T4M should extract this information to identify suitable additive manufacturing resource candidates.

Table 22 summarises the roles of the participants in relation with the value network per business case.

Table 22: VN2 Roles of the participants per use case

Organisation	BC1.1	BC1.2	BC1.3	BC2.1	BC2.2
Moldes URA	Provider			Consumer	Provider + Consumer
ERREKA			Provider		Consumer
Tekniker	Provider	Provider		Provider	Provider

4.2 User roles

Table 23 presents the user roles (i.e., participants’ employees) involved in VN2 that are directly interacting with the T4M Marketplace. To better demonstrate their involvement, the user roles are mapped to the phases described in the previous section.

Table 23: VN2 User roles

ID	Organization	Role	Description	T4M Participation
VN2UR1	Moldes URA (VN2UR1.1) ERREKA(VN2UR1.2)	Procurement responsible (PR)	Responsible for requesting offers, selecting the most suitable provider based on	On demand procurement process • Phase#1: Request manufacturing service

ID	Organization	Role	Description	T4M Participation
	Tekniker (VN2UR1.3)		the provided offer and issuing the purchase order and following up its status.	• Phase#3: Request service quotation • Phase#5: Release manufacturing service offer • Phase#6: Follow up manufacturing service order. • Phase#7: Validate manufacturing service order. • Phase#8: Share performance
VN2UR2	Moldes URA (VN2UR2.1) ERREKA (VN2UR2.2) Tekniker (VN2UR2.3)	Sales responsible (SR)	Responsible for describing the company, the catalogue of manufacturing services, and the list of shipping countries, agreeing on NDA, generating, and negotiating offers, and following up work orders	Providers onboarding process • Phase#1: Provide general information. T4M Marketplace. On demand procurement process • Phase#4: Share manufacturing service offer • Phase#6: Follow up manufacturing service order. • Phase#8: Share performance
VN2UR3	Moldes URA (VN2UR3.1) ERREKA (VN2UR3.2) Tekniker (VN2UR3.3)	IT responsible (IR)	Responsible for supporting the onboarding process of a new provider from a technical point of view.	Providers onboarding process • Phase#2: Grant data access

4.3 T4M Marketplace Information Exchange

This section identifies the main information that will be exchanged in the context of this value network to support ad hoc reconfiguration of supply chains and follow up for the manufacturing service orders.

As described in Section 4.1.1.1, the Information flows in the Providers Onboarding Process involve: provider general info and Provider matching and follow up information.

Table 24: VN2 Provider's onboarding process- exchanged information I

ID	Name	Description	Included Data	Partner involvement
VN2IMO1	Provider's general info	Provider's typical info about the company and services available	• General info of the company: Name, address, contact details. • Catalogue of manufacturing services to be offered (AMS and/or MachS and/ or PIMNS) • List of shipping countries.	Providers (Moldes URA, ERREKA, Tekniker
VN2IMO2	Provider's matching and follow up	Provider's capability, capacity and manufacturing	• Capability: Technical specifications of the manufacturing resources. Involved data vary depending	Providers (Moldes URA, ERREKA, Tekniker

ID	Name	Description	Included Data	Partner involvement
	information	execution information	on the type of machine. • Capacity: Information on the production planning. • Follow up: Information on the manufacturing execution and usage of the manufacturing resources.	

Section C.1, in Annex C offers additional preliminary details on the key technical specifications, outlining the capabilities of the various types of manufacturing resources involved in VN2.

As described in Section 4.1.1.2, the Information flows in the On Demand Procurement Process involve: MS Request, Matching Supply Chain Configurations, MS Request for Quotation, MS Offer, MS Order and Performance.

Table 25: VN2 On demand procurement process- exchanged information I

ID	Name	Description	Included Data	Partner involvement
VN2IMP1	MS Request	Enquiry with preliminary technical requirements	• Identification of the requested Manufacturing Service(s). • Product and process requirements data depending on the specific manufacturing service). (i.e., CAD and 2D drawing for AMS and MachS and process parameters for PIMS) • Number of parts • Material • Whether materials and special dies are sent to the provider. • Selection criteria	Consumers (Moldes URA, ERREKA)
VN2IMP2	Supply chain configuration	Matching supply chain configurations	• Ordered list of providers able to perform the requested service. • Matchmaking information generated by T4M. • Calculated value of the selection criteria.	T4M
VN2IMP3	MS Request for Quotation	Enquiry to pre-selected candidates to get offer	• General information on the MS Request information • Matchmaking information generated by T4M. • Addition information to support the quotation process (if relevant)	Consumers (Moldes URA, ERREKA)
VN2IMP4	MS Offer	Manufacturing service offer submitted by each supply chain configuration.	• General information on the MS Request information • Status of the MS Offer (Released, Rejected, Accepted) Information per offer line (linked to specific manufacturing service) • Provider general information • Price • Delivery Date • Validity period • Special conditions	Consumers & Providers (Moldes URA, ERREKA, Tekniker)

ID	Name	Description	Included Data	Partner involvement
VN2IMP5	MS Order	Manufacturing service order with agreed condition	• General order information • Order Status (Released, Planned, Produced, Shipped, Delivered, Closed, Incidence)	T4M Consumers & Providers (Moldes URA, ERREKA, Tekniker),
VN2IMP6	Performance of procurement process	Performance of the manufacturing service providers based on Quality-of-Service criteria.	Set of objective criteria to be elaborated.	Consumers (Moldes URA, ERREKA)
VN2IMP7	Performance of payment process	Performance of the consumer in terms of payment.	Set of objective criteria to be elaborated,	Providers (Moldes URA, ERREKA, Tekniker)

Sections C.2, C.3, C.4, C.5, C.6, in Annex C offer additional preliminary details on the key data related to MS Request, Supply Chain Configuration, MS Request for Quotation, MS Offer, and MS Order, respectively.

4.4 User stories

In this section, we present the user stories (USs) that were collected and validated through various rounds of VN2 interviews and workshops with the industrial partners of this VN. All USs include the involved user roles, their objective, and the reason why this objective is important.

Table 26: VN2 User Stories

ID	Description
Providers onboarding process phases, information flows and related User Stories	
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.
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.
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.
On demand procurement process phases, information flows and related User Stories	
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.
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
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.

ID	Description
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
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
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.
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.
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.

4.5 User requirements

This section presents the user requirements in the form of use cases (UCs) where the pre-conditions, UC steps, and post-conditions are defined. This is followed by a UML diagram where the involved actors (human roles or systems represented in Figure 22) are depicted.

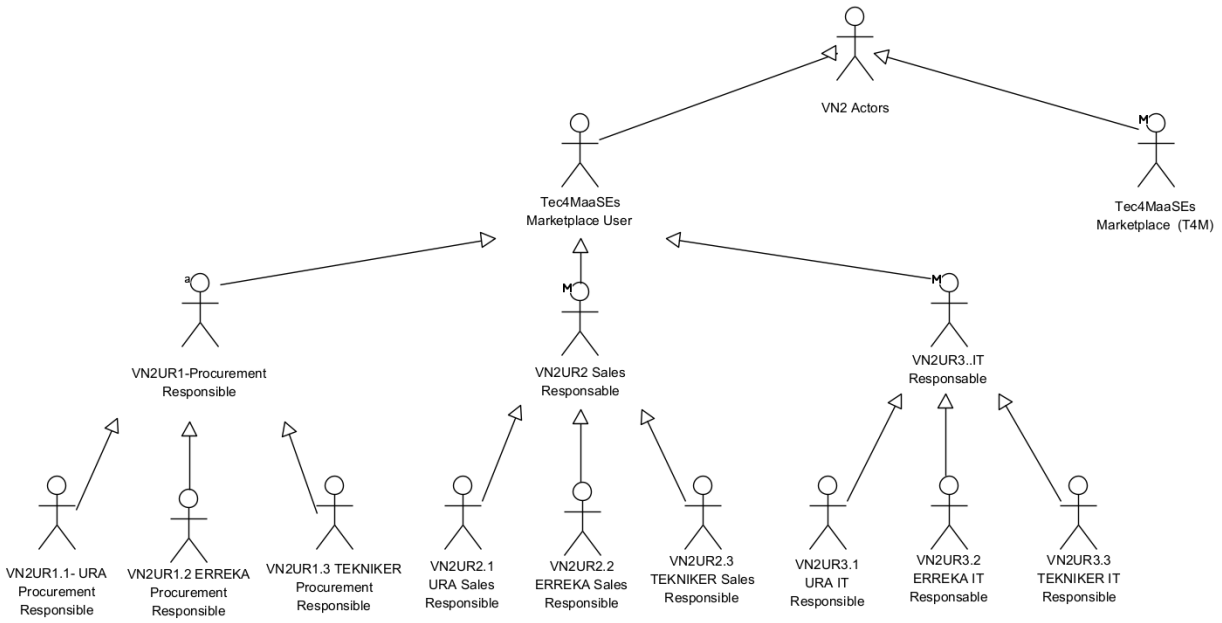


Figure 22: VN2 Actors

These use cases are extracted from the user stories identified in Figure 23 and Figure 27.

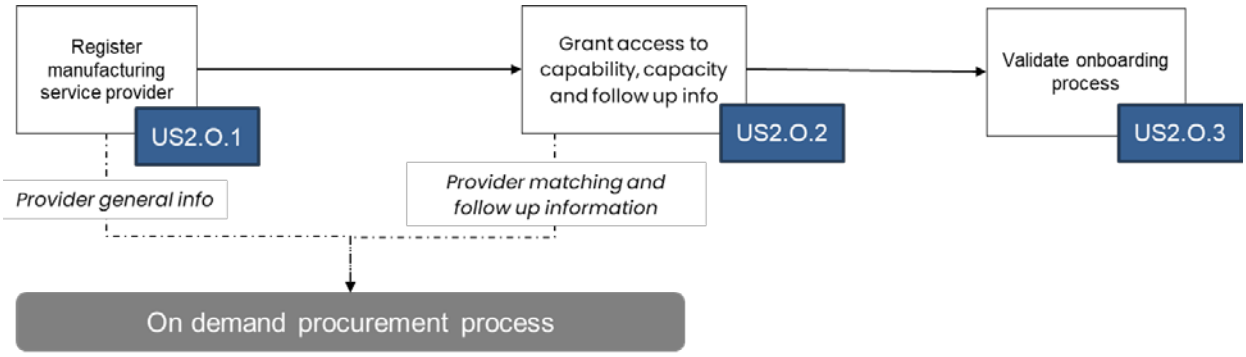


Figure 23: VN2 Providers onboarding phases, information flows and related User Stories

US2.O1

Description: *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.*

This user story is based on a main use case i.e., UC2.O1. Register manufacturing service provider.

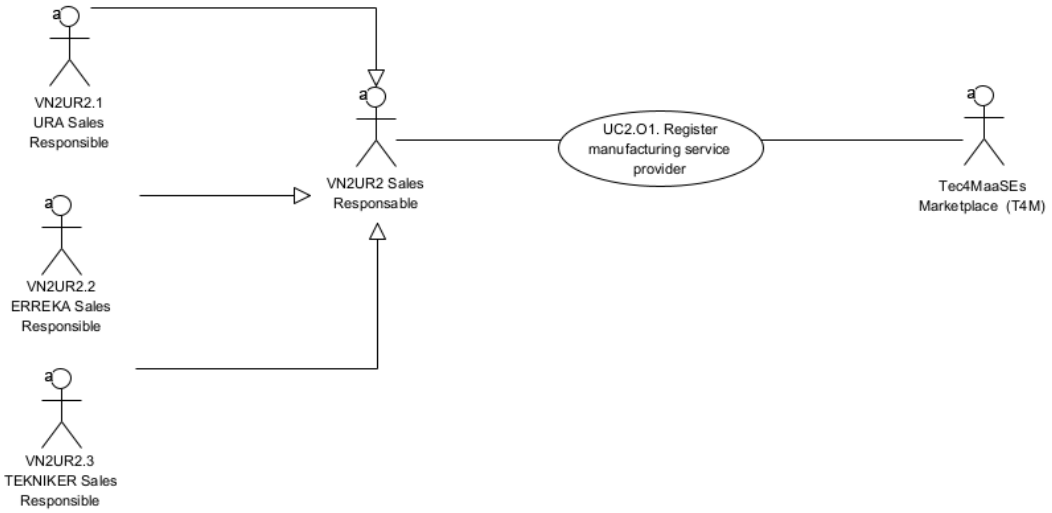


Figure 24: VN2 Use Case diagram for US2.O1

Table 27: VN2 Description of UC2.O1

UC2.O1	Register manufacturing service provider
Brief Description	This use case outlines the actions taken to register a new company as a manufacturing service provider by providing company's general information and identifying the manufacturing services that are being offered on a manufacturing as a service basis.
Initiation	On demand when a new company wants to be registered in T4M as a new provider.
Primary Actors	1. User: Sales responsible (SR)
	2. System: Tec4MaaSEs Marketplace
Pre-conditions	1. SR must be logged in.
	2. Internet connection is available.
Post-conditions	1. Company is registered as potential provider.

UC2.O1	Register manufacturing service provider
	2. Provider onboarding process is initiated.
Basic Flow	1. SR accesses the "Provider's Area to register the company as manufacturing service provider
	2. T4M provides a wizard to include the information required to get specific details about the company, such as the catalogue of manufacturing services (from the list of services supported by T4M), and the list of shipping countries and the acknowledgment of an NDA to ensure the confidentiality of any information from the consumer to which it may have access
	3. SR completes the required information and submits.
	4. T4M checks that the mandatory information has been completed.
Alternative Flow(s)	At step 2, If SR has not completed all the mandatory information T4M informs SR that he/she needs to complete all required information before submitting it.
	If a system error occurs, a message is displayed to SR explaining what went wrong.

US2.O2

Description: *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.*

This user story is based on a main use case i.e., UC2.O2. Grant data access.

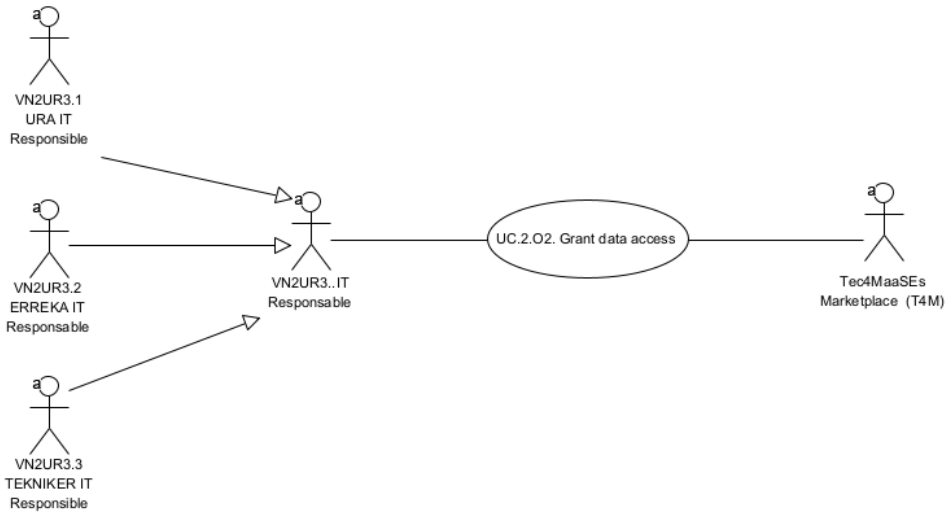


Figure 25: VN2 Use Case diagram for US2.O2

Table 28: VN2 Description of UC2.O2

UC2.O2	Grant data access
Brief Description	This use case outlines the actions taken to complete the onboarding process by granting T4M access to relevant manufacturing-related information in accordance with specific data usage policies.
Initiation	On demand when a new provider wants to grant access to a specific set of datasets and describe usage policies.
	1. User: IT responsible (IR)

UC2.O2	Grant data access
Primary Actors	2. System: Tec4MaaSEs Marketplace
Pre-conditions	1. IR must have the required access rights
	2. Required capability, capacity and manufacturing execution data are available.
	3. Internet connection is available.
Post-conditions	1. Access to required capability, capacity and manufacturing execution data is granted.
	2. Data usage policies are defined.
	3. Acknowledgement of process completion.
Basic Flow	1. IR describes, through the available user interface, the shared datasets including the required information related to manufacturing capacity, capability and execution according to the T4M onboarding conditions.
	2. IR defines, through the available user interface, the usage condition of the exposed information according to the company's internal data governance policies.
	3. IR acknowledges that the process has been completed.
Alternative Flow(s)	If a system error occurs, a message is displayed to IR explaining what went wrong.

US2.O3

Description: *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.*

This user story is based on a main use case i.e., UC2.O3. Validate onboarding process.

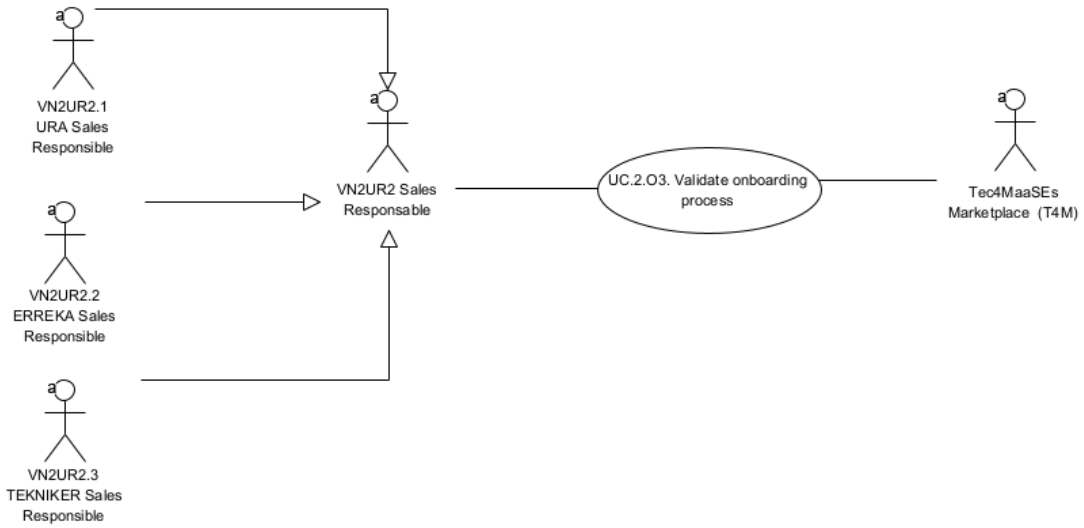


Figure 26: VN2 Use Case diagram for US2.O3

Table 29: VN2 Description of UC2.O3

UC2.O3	Validate onboarding process
Brief Description	This use case outlines the actions required to complete the onboarding process, making the provider eligible to receive new manufacturing service requests.
Initiation	On event when access grating process is completed.

UC2.O3	Validate onboarding process
Primary Actors	1. User: Sales responsible (SR)
	2. System: Tec4MaaSEs Marketplace
Pre-conditions	1. Access grating process is completed.
	2. Internet connection is available.
Post-conditions	1. Provider onboarding process is finalised.
	2. Provider is eligible to receive new manufacturing services requests.
Basic Flow	1. T4M validates the process by checking that the required data have been accessible according to the requirements defined in the onboarding procedure.
	2. T4M notifies the SR that the company has finalised the onboarding process successfully.
Alternative Flow(s)	If a system error occurs, a message is displayed to SR explaining what went wrong.

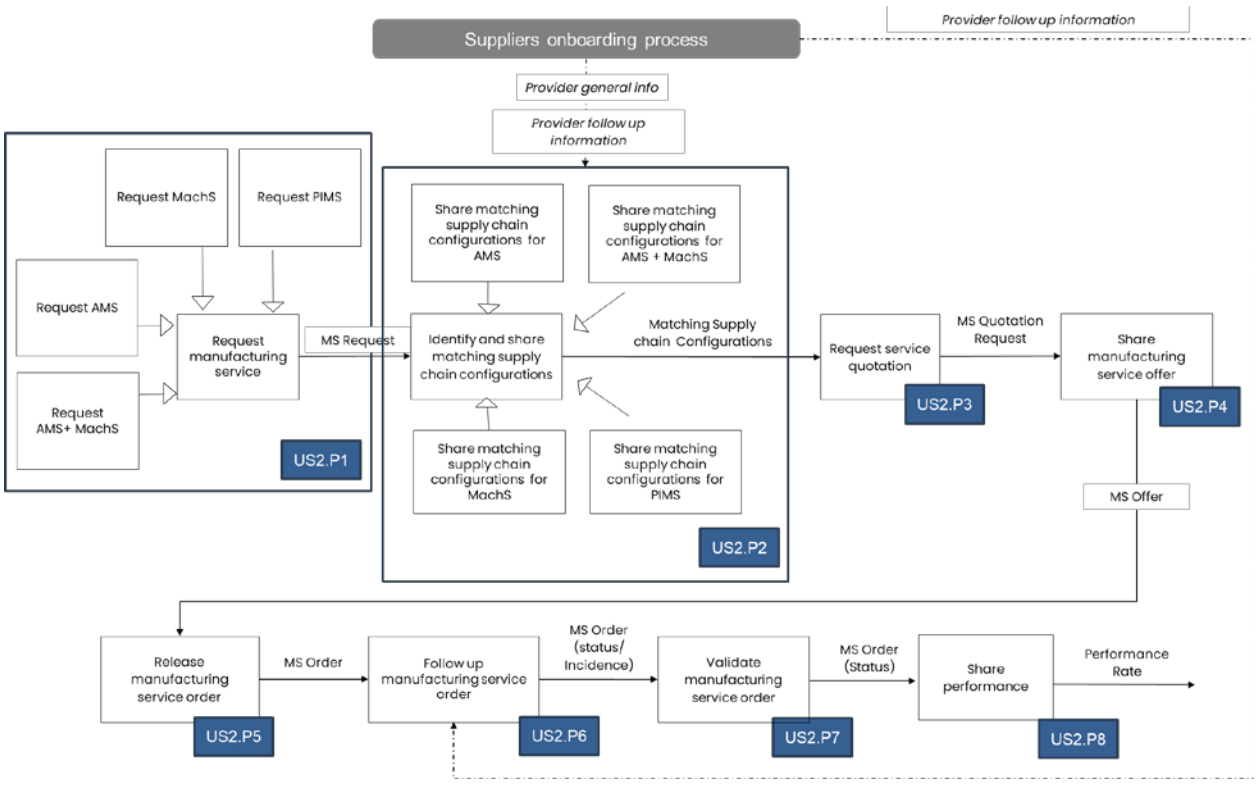


Figure 27: VN2 Procurement process phases, information flows and related User Stories

US2.P1

Description: *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.*

This user story is based on a main use case: i.e., UC2.P1. Request manufacturing service. This use case in turn has two use case specializations as the information required to create a manufacturing service request is based on the specific manufacturing service that is needed but the information needed to request both AMS and MachS is the same. This is reflected on Figure 28 while Table 30 presents the generic UC2.P1.

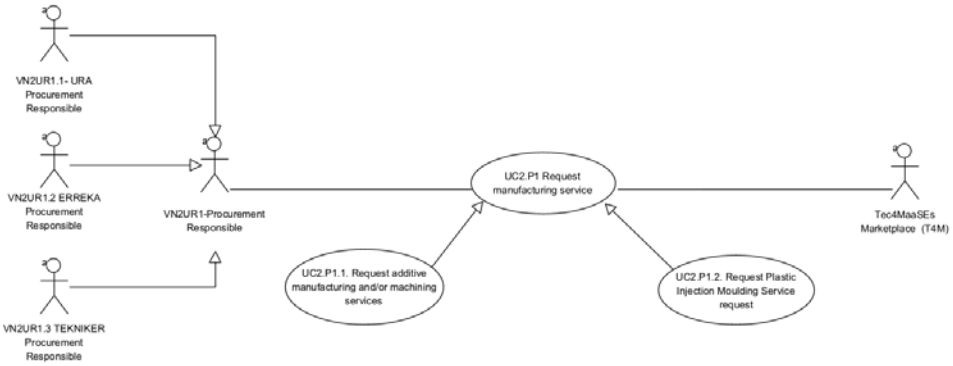


Figure 28: VN2 Use Case diagram for US2.P1

Table 30: VN2 Description of UC2.P1

UC2.P1	Request manufacturing service (additive, machining, plastic injection)
Brief Description	This use case outlines the actions taken to create and submit a new request for a manufacturing service for which the consumer seeks to find matching providers complying with its specific need and selection criteria. This use case outlines the actions taken to create and submit a new request for additive manufacturing and/or machining service or for plastic injection moulding service for which the consumer seeks to find matching providers complying with its specific need and selection criteria.
Initiation	On demand when a new manufacturing service is needed.
Primary Actors	1. User: Procurement responsible (PR)
	2. System: Tec4MaaSEs Marketplace
Pre-conditions	1. PR must be logged in.
	2. Internet connection is available.
	3. Product and process specifications are available.
Post-conditions	1. PR submits a request for a manufacturing service.
	2. T4M ensures a trustworthy exchange of the information provided by the consumer to comply with IPR and privacy issues.
Basic Flow	1. PR selects the Manufacturing Service Request option in Consumer Area.
	2. T4M provides a list of available manufacturing services.
	3. PR identifies the manufacturing service (s) needed.
	4. T4M provides a wizard to include the information required to describe the selected manufacturing service (s) (the needed information is service dependent).
	5. PR creates the manufacturing service request (MS Request) by providing the required information.
	6. PR submits the manufacturing service request (MS Request).
	7. T4M checks that the mandatory information has been completed.
	8. T4M stores the MS Request in the MaaS Consumer's request history so it can be consulted at any time.
Alternative Flow(s)	At step 7, If PR has not completed all the mandatory information T4M informs PR that he/she needs to have all required information validated before submitting the MS Request.
	If a system error occurs, a message is displayed to PR explaining what went wrong.

US2.P2

Description: *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*

This user story is based on two use cases:

- UC2.P2.1. Extract manufacturing service requirements. This use case in turn has three use case specializations as the information to be extracted from the MS Request to identify the matching providers is based on the specific manufacturing service.
- UC2.P2.2. Identify and match the supply chain configurations.

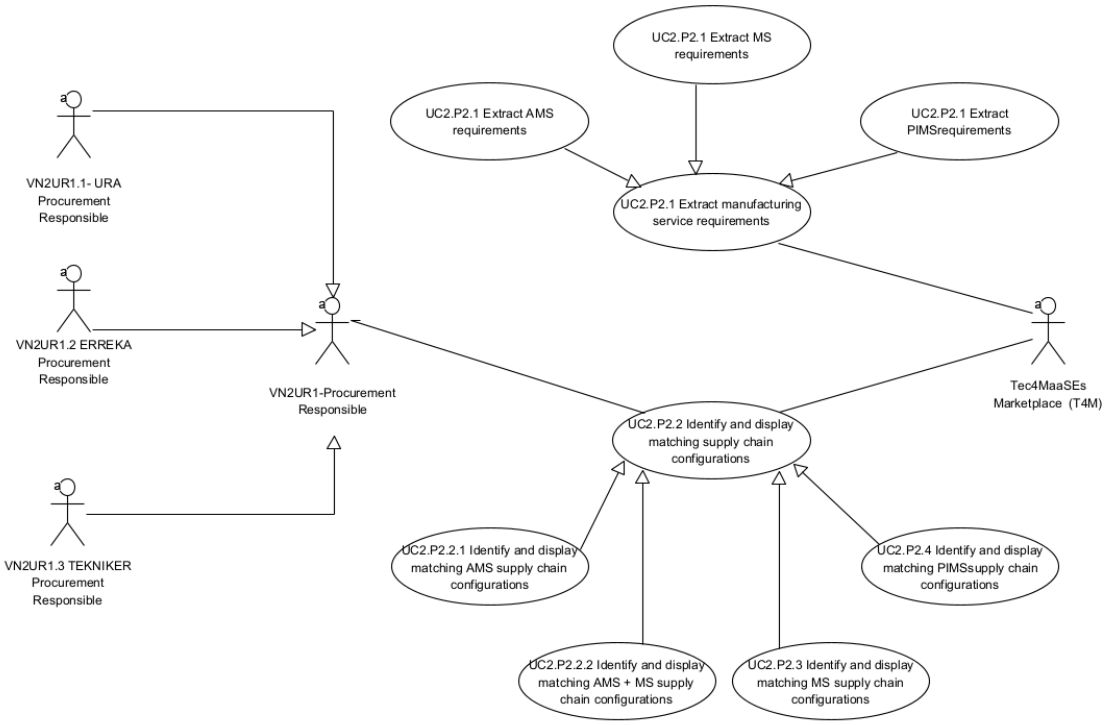


Figure 29: VN2 Use Case diagram for US2.P2

Table 31: VN2 Description of UC2.P2.1

UC2.P2.1	Extract manufacturing service requirements
Brief Description	This use case outlines the actions taken to extract product and process requirements from the information collected in the AMS, MachS or PIMS manufacturing service request. This use case depends on the specific manufacturing service requested (i.e., depending on the specific manufacturing service, a different set of product and process requirements are relevant to identify the matching manufacturing resources candidates).
Initiation	On event when a new manufacturing service request is submitted.
Primary Actors	System: T4M Marketplace
Pre-conditions	1. A complete manufacturing service request is submitted.
	2. Internet connection is available.
Post-conditions	1. Product requirements are identified.

UC2.P2.1	Extract manufacturing service requirements
	2. Process requirements are identified.
Basic Flow	T4M extracts, automatically, product and process requirements from the information collected in the manufacturing service request based on the specific manufacturing service request.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 32: VN2 Description of UC2.P2.2

UC2.P2.2	Identify and display matching supply chain configurations for AMS, MachS and PIMS
Brief Description	This use case outlines the actions taken to identify the matching providers, combine them as supply chain configuration, rank them considering the capability (against the identified requirements) and capacity of the available manufacturing resources along with all the selection criteria and display them in a scoreboard. This use case depends on the specific manufacturing service requested (i.e., depending on the specific manufacturing resources to be involved different matching criteria should be applied).
Initiation	On event when the product and process requirements have been extracted.
Primary Actors	1. System: Tec4MaaSEs Marketplace.
	2. User: Procurement responsible (PR).
Pre-conditions	1. Product requirements are identified.
	2. Process requirements are identified.
	3. Providers are already registered in T4M.
Post-conditions	1. Matching supply chain are identified.
	2. Matching supply chain are ranked according to selection criteria.
	3. Matching supply chain are displayed in the scoreboard.
Basic Flow	1. T4M identifies the providers with manufacturing resources that support the product and process requirements (capability).
	2. T4M identifies, from the previous selection, the providers with appropriate manufacturing resources that are available in the requested period of time (capability).
	3. T4M optimizes and combines them in ranked supply chain configurations according to the specific selection criteria.
	4. T4M displays the selected matching supply chain configurations. The information of each supply chain configuration is broken down in as many lines as requested manufacturing services and displayed in a scoreboard including both additional information and filtering capabilities to support informed selection.
Alternative Flow(s)	At step 4, If there are not matching supply chain configurations a message is displayed.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US2.P3

Description: *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.*

This user story is based on a main use case i.e., UC2.P3.1. Request manufacturing service quotation.

Figure 30: VN2 Use Case diagram for US2.P3

Table 33: VN2 Description of UC2.P3.1

UC2.P3.1	Request manufacturing service quotation
Brief Description	This use case outlines the actions taken to evaluate the proposed matching supply chain configurations, select the most suitable ones and submit quotation requests.
Initiation	On demand when the matching supply chain configurations are displayed
Primary Actors	1. Users: Procurement responsible (PR), Sales responsible (SR)
	2. System: Tec4MaaSEs Marketplace
Pre-conditions	1. PR must be logged in.
	2. Internet connection is available.
	3. Matching supply chain configurations displayed in the scoreboard
Post-conditions	1. Matching supply chain configurations evaluated
	2. T4M ensures a trustworthy exchange of the information provided by the consumer.
Basic Flow	1. PR compares matching supply chain configurations displayed in the scoreboard considering all the provided information and taking advantage of the filtering capabilities.
	2. PR selects the most suitable supply chain configuration(s) from the scoreboard.
	3. PR includes, if relevant, additional information or upload additional documents.
	4. PR submits a request for manufacturing service quotation to gather pricing information

UC2.P3.1	Request manufacturing service quotation
	(including both manufacturing and delivery costs).
	5. T4M checks that the mandatory information has been completed.
	6. T4M notifies the providers involved in the selected supply chain configuration that a new request for quotation is available
Alternative Flow(s)	At step 4, If the PR has not completed all the mandatory information T4M informs PR that he/she needs to have all required information validated before submitting the MS Quotation Request.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US2.P4

Description: *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*

This user story is based on a main use case i.e., UC2.P4.1. Share manufacturing service offer.

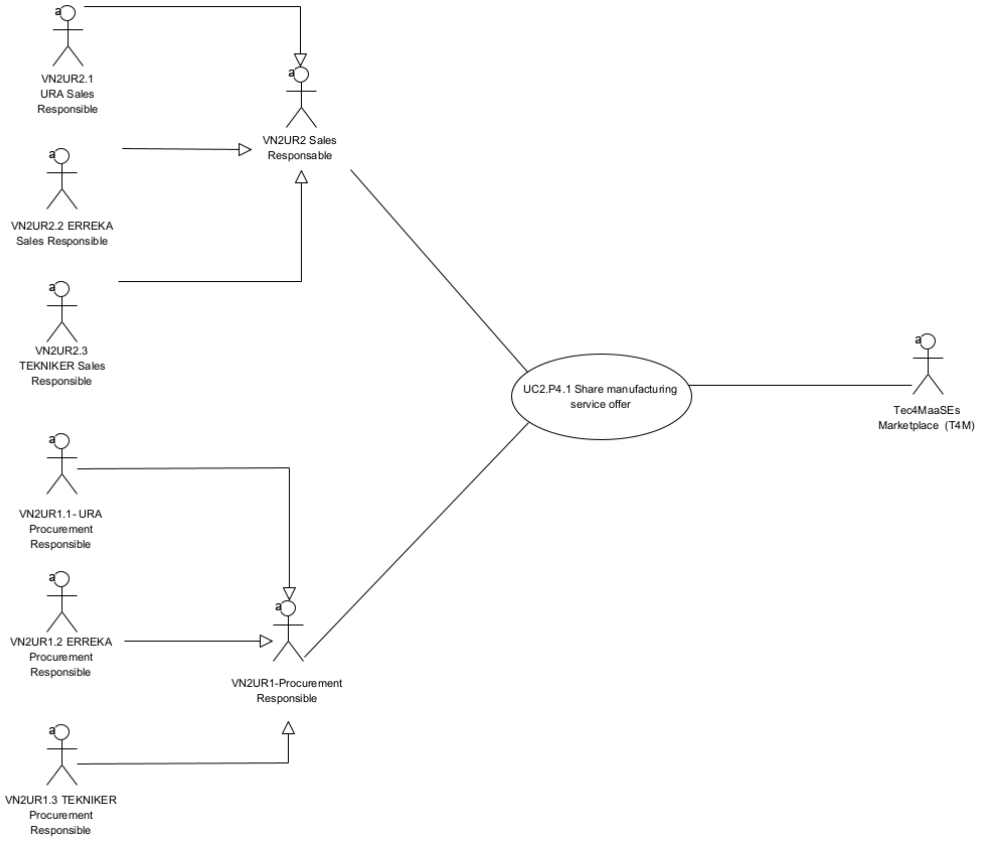


Figure 31: VN2 Use Case diagram for US2.P4

Table 34: VN2 Description of UC2.P4.1

UC2.P4.	Share manufacturing service offer
Brief Description	This use case outlines the actions taken to evaluate the proposed matching supply chains, select the most suitable ones and submit quotation requests.
Initiation	On demand when the manufacturing service quotation request has been submitted and notified.
Primary Actors	1. Users: Sales responsible (SR), Procurement responsible (PR),

UC2.P4.	Share manufacturing service offer
	2. System: T4M Marketplace
Pre-conditions	1. SR must be logged in.
	2. Internet connection is available.
	3. Manufacturing service quotation request are available.
Post-conditions	1. Manufacturing service offer is submitted.
	2. T4M ensures a trustworthy exchange of the information provided by the consumer.
Basic Flow	1. Each SR involved in the selected supply chain configuration accesses the pending MS Request for Quotation in the Providers area that are displayed (grouped by MS Request).
	2. Each SR selects a quotation request from the list.
	3. T4M displays an offer wizard including: • general information provided by the customer in the MS Request along with the criteria that have been considered for the selection as suitable provider, the information of other members in the supply chain and their position in relation to them, as well as any relevant additional information generated by T4M during the matchmaking process (e.g., suitable manufacturing resources, part weight and volume, etc.). • an offer per required manufacturing service, identifying the target provider, to include the price (broken down in manufacturing service, shipping and taxes as separated concepts), the confirmed delivery date, the validity period of the offer (i.e., timeframe during which the offer is considered valid), and any additional observation to specify special conditions or restrictions.
	4. Each SR analyses the general information displayed in the offer wizard, completes the information requested (price breakdown, delivery date, the validity period, and potential comments) in the assigned offer(s) and submits the provider manufacturing service offer.
	5. T4M checks that the mandatory information has been completed in all the offers, as well as the consistency of the delivery dates of the involved manufacturing services.
	6. T4M stores the MS Offer linked to the MS Quotation Request that has triggered it so it can be consulted at any time.
	7. T4M notifies the consumer that a new manufacturing service offer is available
Alternative Flow(s)	At step 5, If a SR involved in the selected supply chain configuration have not completed all the mandatory information T4M informs the SR that he/she needs to have all required information validated before submitting the MS Quotation Request.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US2.P5

Description: *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*

This user story is based on three use cases.

- UC2.P5.1. Review manufacturing service offer conditions.
- UC2.P5.2. Negotiate/clarify manufacturing service offer conditions.
- UC2.P5.3. Release manufacturing service order conditions.

Figure 32: VN2 Use Case diagram for US2.P5

Table 35: VN2 Description of UC2.P5.1

UC2.P5.1	Review manufacturing service offer conditions
Brief Description	This use case outlines the actions taken to evaluate the proposed manufacturing service offers and decide whether initiate a negotiation/clarification phase.
Initiation	On demand when a manufacturing service offer has been submitted and notified.
Primary Actors	1. Users: Procurement responsible (PR), Sales responsible (SR)
	2. System: T4M Marketplace
Pre-conditions	1. PR must be logged in.
	2. Internet connection is available.
	3. Manufacturing service offer is available.
Post-conditions	1. Manufacturing service offer is evaluated.
	2. Negotiation/clarification process is open (if needed).
Basic Flow	1. PR accesses the pending manufacturing service offers through the Consumer GUI.
	2. PR selects a manufacturing service offer from the list.
	3. T4M displays the information related to the selected offer, broken down in offers which include the price (broken down in manufacturing service, shipping and taxes as separated concepts), the confirmed delivery date, the validity period of the offer (i.e., timeframe during which the offer is considered valid), and any additional observation to specify special conditions or restrictions.

UC2.P5.1	Review manufacturing service offer conditions
	4. PR evaluates each offer and decides whether or not to open a negotiation/clarification process.
Alternative Flow(s)	At step 4, PR can agree on what has been proposed and decide not to open a negotiation/clarification process.
	At step 4, PR can decide that it is not worth to open a negotiation/clarification process and reject the offer.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 36: VN2 Description of UC2.P5.2

UC2.P5.2	Negotiate/clarify manufacturing service offer conditions
Brief Description	This use case outlines the actions taken to during a negotiation/clarification process.
Initiation	On demand when a negotiation/clarification process is open.
Primary Actors	1. Users: Procurement responsible (PR), Sales responsible (SR)
	2. System: T4M Marketplace
Pre-conditions	1. PR must be logged in.
	2. Internet connection is available.
	3. Manufacturing service offer is available.
	4. PR has decided to open a negotiation/clarification process.
Post-conditions	1. Manufacturing service offer conditions are updated (if needed).
	2. Negotiation/clarification process is closed (either when an agreement is reached or when no agreement can be reached).
Basic Flow	1. PR selects an offer and initiates a negotiation/clarification process by requesting clarifications/modifications and submitting them.
	2. T4M notifies the involved providers(s) that a negotiation/clarification process has been opened.
	3. PR and SR take advantage of T4M wall to exchange information till an agreement is reached.
	4. SR updates manufacturing service offer conditions. (if needed when an agreement is reached).
Alternative Flow(s)	At step 3, PR can reject the offer if no agreement can be reached.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 37: VN2 Description of UC2.P5.3

UC2.P5.3	Release manufacturing service order conditions
Brief Description	This use case outlines the actions taken to release an order.
Initiation	On demand when the manufacturing service offer conditions acceptable.
Primary Actors	1. Users: Procurement responsible (PR), Sales responsible (SR)
	2. System: T4M Marketplace
Pre-conditions	1. PR must be logged in.
	2. Internet connection is available.
	3. Manufacturing service offer is available.
	4. Manufacturing service offer conditions are clear and acceptable
Post-conditions	1. Manufacturing service offer is accepted.

UC2.P5.3	Release manufacturing service order conditions
	2. Manufacturing service orders is generated.
Basic Flow	1. PR checks final conditions and accepts manufacturing service offer.
	2. T4M transforms the manufacturing service offer in a manufacturing service order (MS Order)
	3. T4M stores the manufacturing service order.
	4. T4M updates the status of unsuccessful the manufacturing service offers (status=rejected).
	5. T4M notifies the providers involved in the selected offer that a manufacturing service order has been released.
	6. T4M notifies the providers whose offers have not been selected that they have been rejected.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

US2.P6

Description: 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.

This user story is based on a main use case i.e., UC2.P6.1 Follow up manufacturing service order. That includes an alternative workflow if a potential deviation is detected.

Figure 33: VN2 Use Case diagram for US2.P6

Table 38: VN2 Description of UC2.P6.1

UC2.P6.1	Follow up manufacturing service order
Brief Description	This use case outlines the actions taken to release an order.
Initiation	On event when the manufacturing service order has been released.
Primary Actors	1. Users: Procurement responsible (PR), Sales responsible (SR)
	2. System: T4M Marketplace
Pre-conditions	1. SR must be logged in.
	2. Internet connection is available.
	3. Manufacturing service order has been released.
	4. Involved providers have been notified.
Post-conditions	1. Manufacturing service order status is updated.
Basic Flow	1. SR of the selected provider acknowledge reception
	2. SR generates an internal work order for the related MS Order (i.e., purchase order).
	3. T4M follows the status of the manufacturing service order and identifies updates (order: planned, produced).
	4. T4M notifies manufacturing service order updates (order: planned, produced) to next provider in the supply chain (if any).
	5. T4M notifies manufacturing service order updates (order: planned, produced) to consumer.
	6. When the parts are shipped, either to the next to the next provider in the supply chain or to the final consumer, the SR updates the status of the related order line (order line: shipped) and provides shipment information through the order wizard.
	7. T4M notifies manufacturing service order update (order: shipped) to next provider in the supply chain (if any).
	8. T4M notifies manufacturing service order updates (order: shipped) to consumer.
	9. When the next provider receives the parts. SR acknowledges reception by updating the manufacturing service order (order: completed)
	10. T4M notifies manufacturing service order updates to consumer.
Alternative Flow(s)	At step 3 T4M can identify a potential deviation in and the order. If this is the case: 1. T4M assesses. the impact of such deviation (e.g. increased deadline, potential penalties. 2. T4M opens an internal incidence linked to the manufacturing service order. 3. T4M notifies the related provider for validation. 4. The SR or the provider assesses the potential incidence and launches mitigation actions (e.g. re-schedule the work order linked to the service order) to close it. If the incidence cannot be solved and remains open. 5. T4M updates manufacturing service order (i.e., updates status=incidence and includes the incidence information) 6. T4M notifies the next provider(s) in the supply chain (if any) about the incidence. 7. T4M notifies the consumer about the incidence. 8. The consumer's PR accesses T4M to evaluate the incidence and decide on potential alternatives (e.g., decide to keep the order as is, cancel the order with no penalty and select a new provider).
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US2.P7

Description: *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.*

This user story is based on one main use case: UC2.P7.1. Manufacturing service order finalisation.

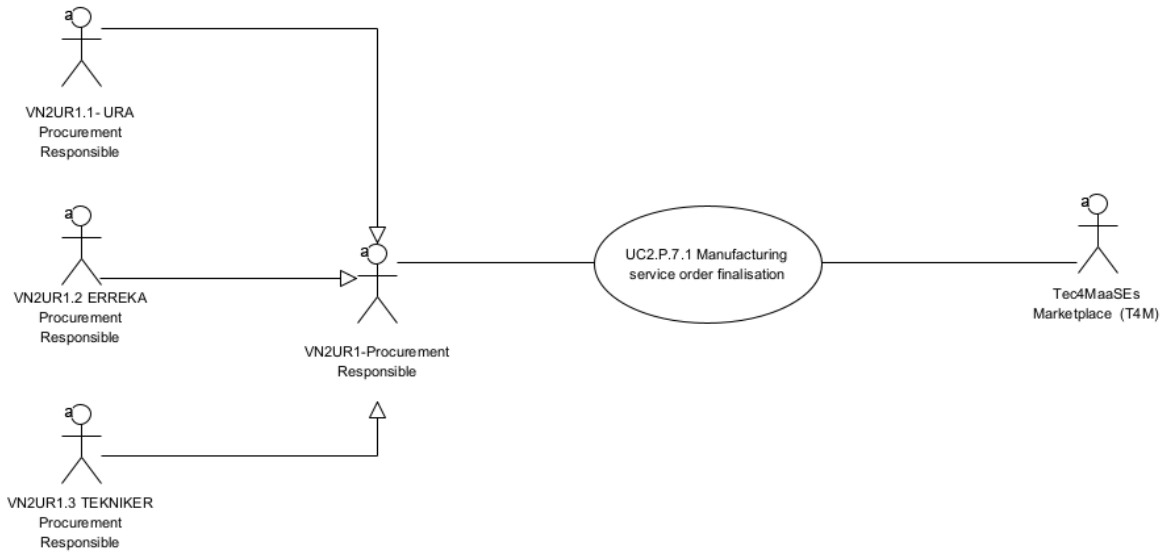


Figure 34: VN2 Use Case diagram for US2.P7

Table 39: VN2 Description of UC2.P7.1

UC2.P7.1	Manufacturing service order finalisation
Brief Description	This use case outlines the actions taken to close a manufacturing service order after it has been validated by the consumer.
Initiation	On demand when the manufacturing service order has been validated.
Primary Actors	1. Users: Procurement responsible (PR)
	2. System: T4M Marketplace
Pre-conditions	1. PR must be logged in.
	2. Internet connection is available.
	3. Manufacturing service order has been delivered to the consumer.
Post-conditions	1. Manufacturing service order status is updated.
	2. Providers involved in the manufacturing service order are notified.
Basic Flow	1. When the parts are received, and validated by the quality responsible, PR closes the manufacturing service order (order: closed)
	2. T4M updates the status of the final order (order: completed)
	3. T4M notifies all the providers involved in the selected supply chain configuration that the order has been closed.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

US2.P8

Description: *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.*

This user story is based on two main use cases.

- UC2.P8.1. Share manufacturing service performance,
- UC2.P8.2. Share payment performance.

Figure 35: VN2 Use Case diagram for US2.P8

Table 40: VN2 Description of UC2.P8.1

UC2.P8.1	Share manufacturing service performance
Brief Description	This use case outlines the actions taken to report on the performance of the manufacturing service and rate the involved providers based on quality-of-service criteria.
Initiation	On demand when the manufacturing service has been validated and closed.
Primary Actors	1. Users: Procurement responsible (PR), Sales responsible (SR)
	2. System: T4M Marketplace
Pre-conditions	1. PR must be logged in.
	2. Internet connection is available.
	3. Manufacturing service has been validated and closed.

UC2.P8.1	Share manufacturing service performance
Post-conditions	1. Providers are rated based on quality-of-service criteria.
	2. Providers rating is updated.
Basic Flow	1. PR reports on the manufacturing service by, including info on compliance with specification, and delivery date.
	2. T4M (re) calculates providers rating.
	3. T4M notifies the involved SR(s) on the availability of new performance reports.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 41: VN2 Description of UC2.P8.2

UC2.P8.2	Share payment performance
Brief Description	This use case outlines the actions taken to report on the performance of the payment process and rate the consumer based on it.
Initiation	On demand when the manufacturing service has been validated and closed.
Primary Actors	1. Users: Sales responsible (SR), Procurement responsible (PR)
	2. System: T4M Marketplace
Pre-conditions	1. SR must be logged in.
	2. Internet connection is available.
	3. Manufacturing service has been validated and closed.
Post-conditions	1. Consumer is rated based on payment performance.
	2. Consumer rating is updated.
Basic Flow	1. SR reports on the manufacturing service by, including info on compliance with agreed payment procedure.
	2. T4M (re) calculates consumer's rating.
	3. T4M notifies the consumer on the availability of new performance report.
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

4.6 Existing systems and related user stories

This section describes the existing legacy systems that are involved in VN2. All systems are mapped to a set of USs.

As described previously (see Figure 23 and Figure 27) the main entry points of data generated by external systems to T4M are the matching and follow up information (i.e., part of VN2IMO2) that must be made available by the providers as part of their on-boarding process, and the manufacturing service request released by the consumer where the product and process requirements (i.e., part of VN2IMP1) are introduced in the form of CAD files, 2D drawings and process data, depending of the manufacturing service. All the rest of information is either provided by the users through dedicated user interfaces or generated by T4M. No data is exported from T4M to external systems.

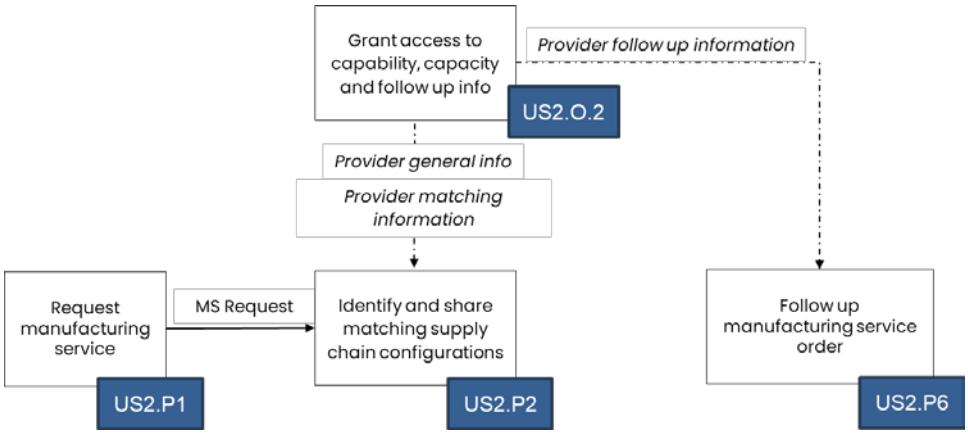


Figure 36: VN2 On boarding and On-demand Procurement processes

On the one hand, access to capacity and manufacturing execution data (VN2IMO2) is granted as part of US2.O2 and, on the other hand, product and process data provided as part of the MS Request (VN2IMP1). These two inputs are used by T4M for matchmaking purposes in US2.P2.

Table 42: VN2 Available legacy systems, data sources and available data

Value Network company	Existing Data Source	Related US	Related information	Data (Import)	Data format
Moldes Ura	Internal Datasheets	US2.O2, US2.P2	VN2IMO2	Production planning data	(.xls)
	Manufacturing execution Database	US2.O2, US2.P6	VN2IMO2	Manufacturing execution data	(.xls)
Erreka	eXPertis Enterprise Resource Planning (ERP)	US2.O2, US2.P2	VN2IMO2	Production planning data	(.xls)
	MAPEX Manufacturing execution system (MES)	US2.O2, US2.P6	VN2IMO2	Manufacturing execution data	(.xls)
Tekniker	Production planning datasheet	US2.O2, US2.P2	VN2IMO2	Production planning data	(.xls)
	Smart Factory Hub	US2.O2, US2.P6	VN2IMO2	Manufacturing execution data	(.json)
Moldes Ura	CIMATRON CAD/CAM System	US2.P1, US2.P2	VN2IMP1	CAD File	(.step)
		US2.P1, US2.P2	VN2IMP1	2D Drawing	(.pdf)
Erreka	SIEMENS NX CAD/CAM System	US2.P1, US2.P2	VN2IMP1	CAD File	(.step)
		US2.P1, US2.P2	VN2IMP1	2D Drawing	(.pdf)
	Plastic injection process parameter data sheet	US2.P1, US2.P2	VN2IMP1	Process data sheet	(.xls)

Value Network company	Existing Data Source	Related US	Related information	Data (Import)	Data format
Tekniker	SIEMENS NX CAD/CAM System	US2.P1, US2.P2	VN2IMP1	CAD File	(.step)
		US2.P1, US2.P2	VN2IMP1	2D Drawing	(.pdf)

Annex D provides details on the existing legacy systems in each company involved in VN2 and the that are currently available.

4.7 KPIs, Calculation Methods and Base lines

This section describes the KPIs that will be used to assess the T4M tangible (measurable) impact of the VN2 pilot. The assessment involves the comparison of the as-is and the to-be situation. This comparison is based on specific KPIs which are defined in terms of (a) the objective that is required, (b) the baseline of the KPI (as-is situation) and (c) the target value of the KPI after the T4M implementation.

Table 43: VN2 KPI summary

KPI	Partner	As-Is	To-Be
Machine Capacity Utilization Rate	Ura	X*	+15%
	ERREKA	X	+10%
	Tekniker	X	+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	X	Reduction of inventory costs of spare parts by 25%
Product lead time	Ura	X	-25%
	ERREKA	X	25%
	Tekniker	X	25%

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

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.

Calculation Method and/or Actual Formula: 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.

$$Machine\ Capacity\ Utilization\ Rate = \frac{Actual\ Machine\ Hours\ Used\ \ (in\ period)}{Total\ Available\ Machine\ Hours\ (in\ period)}\ x\ 100$$

Related Data:

- *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.

Data Resources

- *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. Total Available Machine Hours.
- *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 SmartFactoryHub, and accessible through an API.

Baseline

In the framework of T4M this KPI is calculated at manufacturing section level (i.e., Machining for Moldes URA, Plastic injection moulding for ERREKA, and Additive manufacturing and Machining for Tekniker). The baseline will be calculated at the beginning of the validation phase.

Goal

- *Ura:* Increase the baseline percentage for each manufacturing section by 15%.
- *ERREKA:* Increase the baseline percentage for plastic injection section by 10%
- *Tekniker:* Increase the baseline percentage for each manufacturing section by 15%

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.

Calculation Method and/or Actual Formula: 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

Related Data:

- *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.

Data Resources

Data related to Supplier Selection Time, Order Preparation Time and Order Transmission will be accessible from T4M. Baseline values are experience based.

Baseline

The baseline will be calculated at the beginning the validation phase.

Goal

Reduce the baseline value of Order *Placement Time* by 25% for all the involved contractors (i.e., Moldes Ura, ERREKA, Tekniker). To calculate the reduction the baseline will be compared to the mean *Order Placement Time* during the validation period.

KPI: Reduction in Investment Costs (Ownership vs. Service)

Description: 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

Calculation Method and/or Actual Formula: 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:

$$\text{TCOOwnership}\ (in\ period) = \frac{\text{TCOOwnership}}{service\ life}\ x\ \text{period}$$

$$\text{TCOService}\ (in\ period) = \sum \text{Cost of Additive Manufacturing services}\ (in\ period)$$

Related Data:

- *TCOOwnership:* It 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:* It represents the aggregated costs of Additive Manufacturing services requested in a given period.

Data Resources

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.

Baseline

Not applicable

Goal

Reduction of investment costs value of 15% during the validation period.

KPI: Storage cost of spare parts (Investment costs in stored 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.

Calculation Method and/or Actual Formula: The KPI is calculated by multiplying the spare part cost by the minimum required spare part number. At the moment, 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:

- List of critical spare parts
- Minimum required quantity
- Individual cost

Data Resources

Data related to spare parts is managed through Erreka's ERP system.

Baseline

The baseline will be calculated at the beginning the validation phase.

Goal

Reduce inventory costs of spare parts by 25%.

5 Value Network 3: Requirements and KPIs

5.1 Description

The business domain of the VN3 is the construction of facilities for the Hydrogen Market. This involves trilateral interactions between three different sets of general stakeholders namely (a) *the Large Energy Producer (LEP)*, who orders the facility, (b) *the Engineering, Procurement and Construction contractor (EPC)*, who designs/develops and provides the facility and (c) the companies that build the equipment needed for the facility, acting as *the provider of the EPC*. The EPC stakeholder (AIBEL in our case) plays a central role in this value network, and is acting as the focal point around which this case evolves.

Aibel is a Norwegian EPC contractor with long experience in the Oil & Gas industry and has become a leading European provider of sub-stations for offshore wind farms. Currently, Aibel is positioning itself in the emerging European hydrogen market as a system integrator and EPC contractor. A large-scale hydrogen facility project is a capital project with a budget in the range of billions of euros and as such its design, development, deployment and operation are of crucial importance. The benefits of T4M in the present value network will be examined via a use case that is based on Aibel's portfolio of construction projects. In the course of the facility development project the distinct phases in which the EPC (AIBEL) is involved include:

- The identification of components in the to-be facility from a system breakdown (decomposition of what constitutes a Large Facility into components and subcomponents). This step requires internal work by different engineering systems, towards deriving a set of potential equipment packages needed and upon which the procurement phase (and respective steps) will take place.
- Once components have been identified and specified to a degree that they can be priced and logged in a project plan, interactions with pre-selected eligible providers takes place with several iterations until a procurement agreement is established. The procurement agreement is in the form of a Purchase Order issued by the Contractor to each Provider (one per equipment package).
- Lastly, the EPC executes the project until the delivery date and in this phase a set of trilateral exchanges of information take place to ensure the appropriate delivery of equipment and their deployment in the field. In this step it is important to note that (a) The equipment packages of such complex facilities are characterized by a high degree of customization, which in turn implies that provider and contractor must collaborate closely in this process of development (b) after a purchase order is issued, there might be changes in any part of the process which should be reflected by updates of the purchase order with new requirements and specifications. Following that iterative process from the Purchase Order onward, the contract is completed when the facility is ready to start-up.

Overall, the aforementioned discrete phases require integrated system information, as critical steps are currently conducted offline leaving room for potential errors, miscommunications and delays. On that account, the goal of VN3 is to improve coordination with providers, and in particular improve the iteration time, in all phases of the project execution through a MaaS approach. The envisaged way to achieve this is by shifting from a document-based information exchange protocol to an information model-based interaction that will be shared across the involved stakeholders, become updated and ultimately used to track all interactions throughout the process.

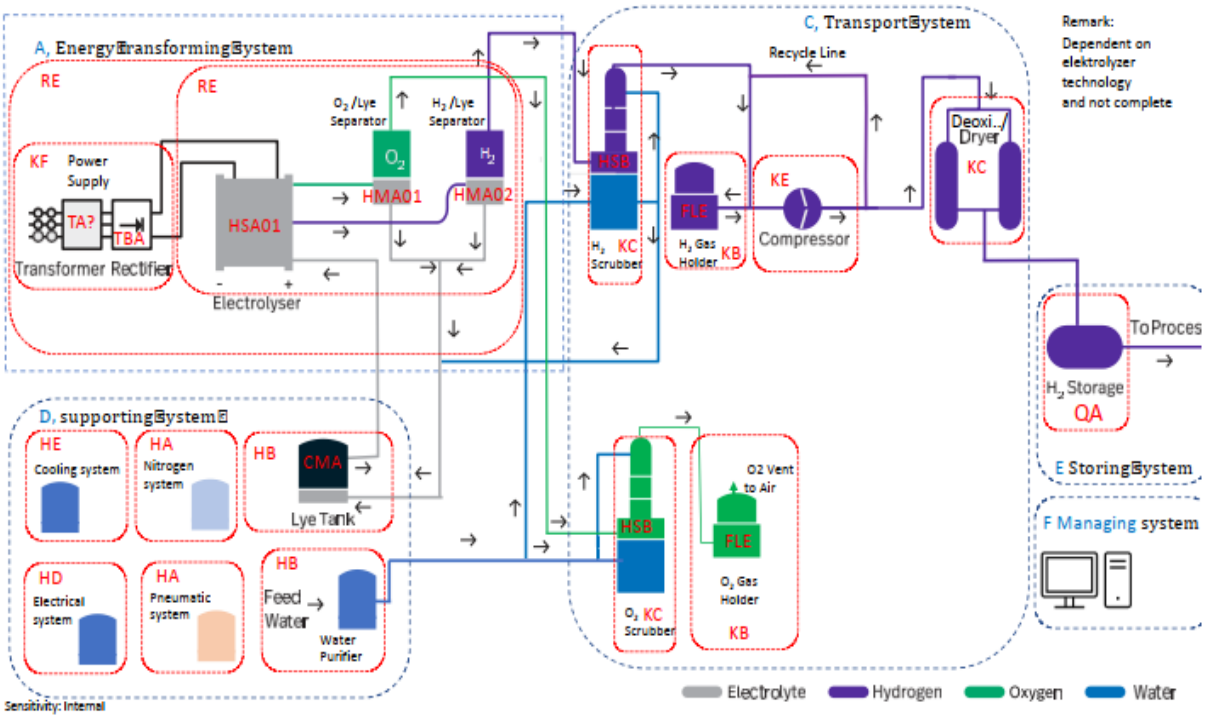


Figure 37: VN3 Ecosystem

To exemplify the breadth and depth of the needed equipment for a facility, Figure 37 presents an indicative Hydrogen Facility the EPC is commissioned to develop. Having completed a system breakdown, AIBEL is in charge of delivering systems A-F, with each system having several sub-systems components and sub-components. As mentioned above, some of these components have good availability because they are standard parts with predefined requirements (e.g. a pipe). Others though are tailor made for the commissioned facility and thus they are not readily available, while all components should be integrated and tuned in order to synthesize a Large Energy Production Facility. Aibel then must select the most suitable among a set of pre-qualified providers for all such sub-systems and components.

The selection of the sub-systems and components is finalized by assigning a unique designation to each, facilitating efficient information exchange. Based on these unique designations, AIBEL must develop appropriate information models. Given that interactions occur across a value network with providers using their own legacy systems, it is essential to: (a) enable seamless and effective integration of each partner's input/output within the value network and (b) provide the capability to interact with, extend, comment on, and update each information model to accurately reflect real-world interactions during a facility development project.

Having described the overarching goal of VN3, the following sections provide an in-depth exploration of the steps involved in facility development. This includes the role of the T4M solution and the stakeholders involved in each sequential phase, from the registration (onboarding) of all stakeholders to the completion of the facility provision under a MaaS approach. As T4M transitions from document-based information exchange to an Information Model-based exchange within this value network, the phases align with the corresponding information models. The overall phases are illustrated in Figure 38.

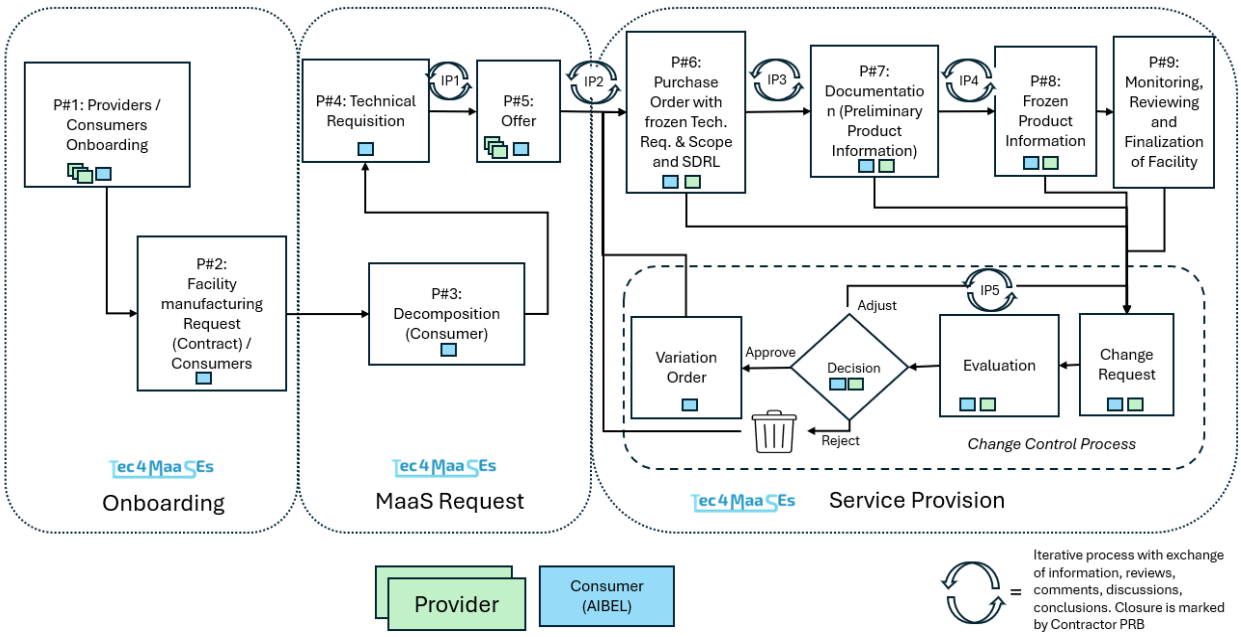


Figure 38: VN3 Facility development through T4M

Phase #1: Consumer / Provider registration

In order to harvest the benefits of the T4M, the first phase consists of the Onboarding of the Stakeholders. That includes the Consumer (EPC Contractor - AIBEL) and the Provider(s) along with the registration of their respective assets and capabilities. In this phase users with access to the system and respective authorities register to T4M. We identify the following two users:

1. Package Responsible Engineer (PRE) and Package Responsible Buyer (PRB) for the Consumer (AIBEL)
2. Package Responsible Buyer for the Provider(s)

Phase #2: Contract provision to develop a new large energy production facility

Every facility development project begins with bilateral discussions between the LEP (Facility Owner) and the EPC Contractor (Consumer) that acts as a proxy in the scope of T4M. These discussions result in the signing of a contract for developing the Energy Production Facility. The contract also outlines the project requirements, which include regulations from authorities as well as mutually agreed specifications and standards for the design, development, and delivery of the facility. Although this step falls outside the T4M project's scope, it serves as the initial entry point of information that will be utilized in the information models in subsequent phases. As such the Consumer (AIBEL) acting on behalf of both parties in the contract provides the Contract (relative information needed) to the T4M, initiating thus a new Project within the T4M scope.

Phase #3: Decomposition – Bill of components for a large energy production facility

Once the contract is in place, AIBEL's engineering teams begin internal work to identify the various potential setups for the facility and determine the components and subcomponents that will form the base systems to be procured from different providers. Developing a Large Energy Production Facility involves extensive engineering to specify specialized equipment that does not currently exist. This is a special case of a highly customized product/service that concerns the decomposition of the future facility into its components and subcomponents and should be regarded outside the scope of T4M. Instead, AIBEL will directly provide the bill of components (i.e. the decomposition) to the T4M information models in subsequent steps.

Phase #4: Technical requisition: Issuing of an Enquiry with preliminary technical requirements to selected providers

In this step, the consumer (AIBEL) undertakes two key actions: (a) introducing the Bill of Components (i.e. the decomposition) to the T4M system, and (b) issuing an Enquiry with preliminary technical requirements and commercial conditions to selected pre-qualified providers. To create the technical requisition and supporting documents, various engineering departments within AIBEL leverage their expertise and respective engineering systems. The result of these efforts is the so-called "Technical Requisition" which constitutes the first version of the Consumer Information Model (CIM), which now encompasses information about the preliminary technical requirements of the needed equipment. This includes the specifications, standards and datasheets detailing functional requirements such as operating temperatures, pressure and flow. This CIM is the main information model that will be enhanced / transformed / extended in the course of the overall project.

There is one CIM per equipment package compiled by many individuals under the responsibility of AIBEL's PRE. Within the T4M framework, any updates to the CIM are managed by the PRE. In this phase, the CIM is finalized with the authorization of AIBEL's PRB, and the process advances to the issuance of the Enquiry. The Enquiry is sent to minimum three pre-qualified providers who have signed an NDA, making them eligible to receive the Enquiry. Additionally, the Enquiry has a fixed active period within which all providers must submit their offers to the given Tenders.

Phase #5: Tender / Offer(s) – detailed product specification inclusion

After AIBEL issues the Enquiry through T4M, the selected providers receive a notification about the newly issued Enquiry along with access to the corresponding CIM. From the providers' perspective, the received CIM must be processed to determine the scope and context of the tender and thus shape their Offers. Upon receiving the CIM, each provider integrates it into their own system and processes it to produce a potential Offer, outlining the components and sub-components they can develop and deliver. This process must be completed while the Enquiry is active and before the respective deadline.

Since phases 4 and 5 involve the processes of issuing an Enquiry and submitting an Offer to the Tender, additional parameters must be considered within an Iterative Phase (IP#1) as follows:

Iterative Phase (IP) #1: Technical requisition -> Offer submission

During the period that the Enquiry is active, all the providers can issue queries / questions to AIBEL's PRE through T4M. These queries are introduced as annotations on certain parts of the CIM and AIBEL's PRE receive notifications when this happens. Queries and replies are broadcasted to the providers.

AIBEL may update the CIM at any time with additional information, and all providers are immediately notified of these updates. Providers can then proceed by submitting their offers based on:

- the initial Enquiry,
- the updated Enquiry,
- both with the initial Enquiry and the updated Enquiry.

Providers can submit their final Offer (to be considered for evaluation and selection) at any time before the Enquiry deadline. All communication and data exchange occur between the PRE of the consumer (AIBEL) and the respective PREs of the providers and all communications from the PRE of the consumer are first validated

by the PRB of the consumer prior to their communication to supplier(s)' PREs. From the provider's perspective, the outcome is an "Offer" which constitutes the first version of the Provider Information Model (PIM), for the respective equipment package, which includes "Preliminary Product Information" and commercial information as well. For AIBEL, the outcome is the receiving of the Offers – i.e. Different PIMs from the Providers. This phase concludes either with (a) the receiving of each provider's offer or (b) the deadline set by AIBEL's PRB.

At the end of IP#1, AIBEL has all the final offers in the Tenders for all component packages. A second iterative process is initiated at this point that concerns the evaluation and selection of the providers that will receive a purchase order.

Iterative Phase #2: Consumer reviews the submitted offers

In this phase, the consumer has received the typically three PIMs from the respective providers for each Enquiry. Similar to the previous phases, a series of transformations is conducted to integrate the PIMs into the engineering systems, followed by engineering work that ultimately results in the selection of the final set of equipment that will form the to-be-developed facility. The PRE of AIBEL is responsible for overseeing the technical work in this phase. Additional considerations include:

- During the tender evaluation process, AIBEL may need additional information from a provider, leading to iterative annotations on the PIM with questions and answers.
- This phase is typically completed within 2-3 months after the Enquiry.

The evaluation of the submitted Offers per Tender is now complete, and the provider(s) selected by AIBEL to receive the purchase order have been finalized. This marks the initiation of the T4M service provision. In the subsequent phases (P6-P9), there may be requests for amendments. To manage these, we introduce a "Change Control Process" along with an iterative process to handle such requests efficiently.

Change Control Process (includes IP#5)

The production of a facility for energy production is a very challenging task, often requiring adjustments as new information arises, which can change the composition of the plant. To account for these necessary changes and ensure successful development, the "Change Control Process" is initiated whenever a change is identified in any phase. This process ensures that new circumstances are addressed and decisions are made to facilitate project progression. The overall change request process is as follows:

- A "Change Request" (CR) can be issued by either the Consumer (AIBEL) or the Provider when a need arises, but always after a PO is placed. It must cover all changes to frozen requirements or designs all the way to the finalization of the overall Project under Contract.
- The Change Request is evaluated for its implications, which must be jointly understood. An optimal resolution for the project is sought, considering quality, time, and cost. The CR can be adjusted during the evaluation process through the Iterative Process (IP) #5, involving multilateral exchanges of information, annotations, and comments to refine the request.
- Having completed the evaluation of the implications, a CR can be either approved or rejected.
- Rejected change requests do not change the purchase order
- Approved change requests lead to the creation of a Variation Order (VO) that in-turn updates the CIM and PIM with the respective approved changes. The update means that the CIM now also holds the given Variation Order

Phase #6: Purchase order – Issuing of a purchase order for a product package to a selected provider as well as the Provider Documentation Requirements List (PDRL)

In this phase, the evaluation of the submitted tenders is completed, and the provider(s) selected by AIBEL to receive the purchase order are finalized. AIBEL then issues the Purchase Order, which constitutes the binding contract to be honoured and then the CIM is updated to include more information relevant to the current phase. This marks the initial phase of the T4M service provision. Additionally, in this phase the "Provider Documentation Requirements List" (PDRL) is created appended to the CIM and transferred to the provider. The PDRL is a part of the technical requirements, and gives the requirements to the provider regarding documentation and information that shall be delivered.

Additional parameters that need to be taken under consideration as follows:

- From this phase onwards only one provider proceeds as there is only one PO per equipment package (Enquiry), meaning that there is only one CIM and one PIM from this phase on.
- All other providers cease to have access to any evolutions of the CIM.
- This phase finishes within 2-3 months after the Enquiry.
- The PO (and all communications) is validated by the PRB for security purposes.
- The CIM is issued along with "Frozen Technical Requirements," which are similar to the previous versions of requirements but are now finalized. These requirements remain fixed unless a Change Control Process is initiated, resulting in a Variation Order (VO). Alternatively, a specific time for finalizing the frozen requirements may be agreed upon.

Iterative Phase 3: Consumer – Provider

Moving from Phase 6 to Phase 7, Iterative Phase 3 occurs through the T4M system. This phase allows stakeholders to exchange information, reviews, comments, and hold discussions based on the CIM and PIM. The goal is to reach conclusions that enable them to proceed to Phase 7 and eventually release the documentation with preliminary product information.

Phase #7: Documentation phase that updates the PIM - Issue of documentation with preliminary product information

In this phase the providers return to AIBEL "Documentation" that are appended to PIM in this phase that outline the preliminary product information on the equipment they have received the PO (purchase order). In order to be able to do so, similarly as in the previous phases, the providers PRE receives the CIM having the frozen technical requirements, part of which needs to be integrated into their own design systems and be processed ("perform engineering work") to be able to produce the respective preliminary product information to be introduced in the CIM in this phase. As in this step close collaboration is needed the Iterative Phase 4 takes place where AIBEL's PRE and the PRE of the provider interact on top of various fields in the PIM. In this phase it should be noted that the Provider's product information can also contain some specific requirements upon the consumer's design. For instance:

- Requirements for utilities (electrical power, cooling, drain, maximum deflexions/movements of supporting structures, etc.)
- Design requirements like length of straight pipe before and after a flow meter.

Note that the “Change Control Process” can be initiated at any point where the evolution of the pilot requires a requirements’ change and this process is actually included in the service provision phase leading to a variation order.

Iterative Phase #4: Consumer – Provider

Moving from Phase 7 to Phase 8, Iterative Phase #4 takes place through the T4M system. This phase enables stakeholders to exchange information, reviews, and comments, and hold discussions based on the active Information Model (PIM) in this phase and with the respective information it holds. The aim is to reach conclusions that allow them to proceed to Phase 8 and issue frozen product information on the PIM. Specifically, AIBEL’s PRE issues requirements, comments, and reviews within the PIM, which are then transferred to the Provider. The Provider’s PRE examines these inputs, conducts their own engineering work, and responds by including additional information and responses in the PIM. This response is then reviewed by AIBEL’s PRE, who also conducts further engineering work and responds accordingly. Each comment and review is tracked and logged. The phase is completed when all product information is approved by the Consumer (EPC Contractor - AIBEL). Similar to the previous phase, the “Change Control Process” can be initiated at any point if changes to requirements are necessary due to the project's evolution.

Phase #8: Frozen Product Information appended to PIM - Issue frozen product information

In this phase, the provider considers and responds to all reviews and comments, and then issues the "Frozen Product Information" on the PIM. The PIM includes all the information on the specific equipment to be developed, delivered, and installed in the facility. Thus, the combination of the CIM and PIM in this phase forms the basis for the final equipment to be manufactured. As with the previous phase, the “Change Control Process” can be initiated at any point if a change in requirements is needed due to the project's evolution.

Phase #9: Consumer-Supplier Interaction until Facility is Operational, Project Completion, and Expiry of Guarantee Period

With the CIM and PIM as the basis for what is to be delivered, Iterative Phase #5 remains active until the project is finalized, the facility is operational, and the guarantee period has expired. During this phase, bilateral communication continues in a manner similar to previous iterative phases. The submitted PIM is processed sequentially through a) AIBEL issuing comments and reviews on all parts of the IM, which are then transferred to the provider and b) the provider responding accordingly. Additional engineering work may be required by both AIBEL and the provider during this phase. All comments and reviews are tracked and logged. This phase remains open and active until the facility is fully operational and the guarantee period has ended. As in previous phases, the “Change Control Process” can be initiated at any point if changes in requirements are needed due to the project's evolution.

The previous iterative phases and the change control process constitute the steps required to develop a facility, starting from the on boarding of stakeholders in the T4M system to the final delivery of the facility. Currently, this interaction is conducted through sets of different documents, which presents several issues. These issues arise because the content in the sets of documents per phase requires information from various engineering systems to be produced from both the consumer (AIBEL) and providers' perspectives. Consequently, all phases involve processes that consume time and resources and are prone to errors. To address these challenges, T4M aims to transform the PDF-based process into an Information Model (IM)-based process enabled by the platform. This transformation will offer all involved stakeholders a more efficient way to exchange information. The T4M platform will leverage Asset Administration Shell (AAS) and

IM-based interactions to enhance data interchange. Specifically, the value network will focus on improving the interchange of data and documents between the consumer and the providers. This improvement aims to mitigate the issues arising from exporting data from engineering systems, formatting it into documents, creating PDF files, and issuing them to consumers and providers, and vice versa. Therefore, the main focal point is the implementation of the information models illustrated in Figure 39 that streamline these processes.

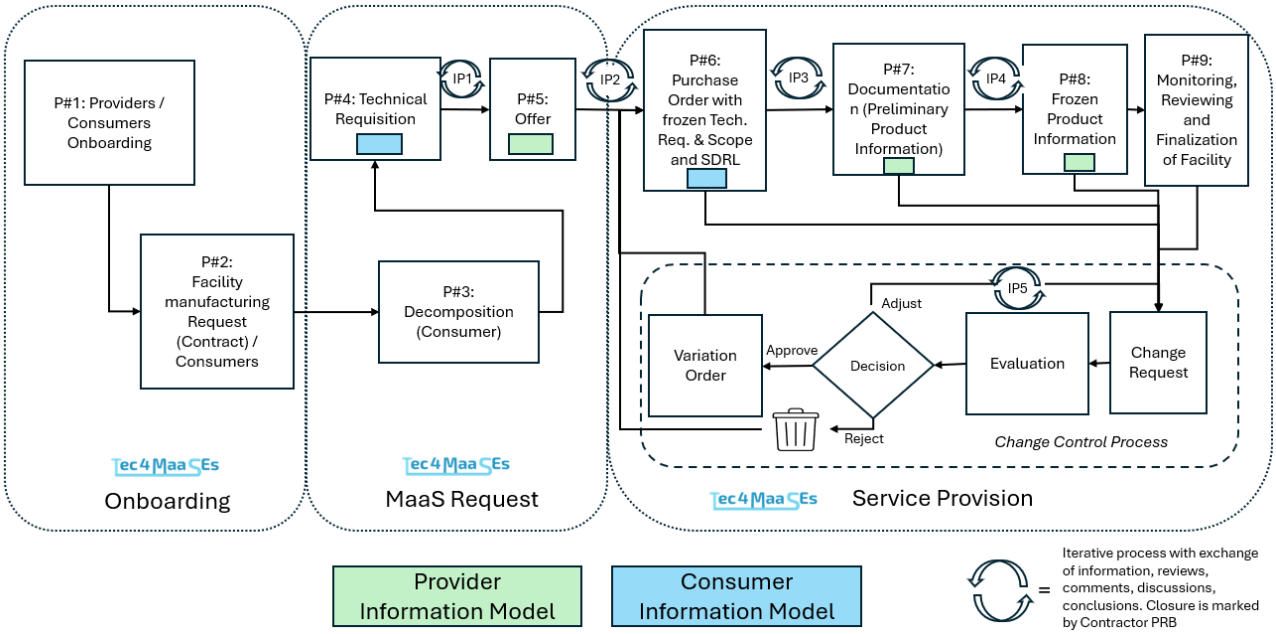


Figure 39: VN3 Information Model

5.2 User Roles

In this section we present the involved user roles, i.e. employee roles that participate in the facility production from the side of the Consumer (EPC contractor – AIBEL) and Suppliers within the present Value Network.

Table 44: VN3 User Roles

ID	Organization / Role / Description	T4M Role
VN3UR1	**Organization** AIBEL **Role** Package Responsible Buyer (PRB) **Description** The PRB is working in the Procurement department and is	• **P1:** Consumer Sign/up, Access Provision to Suppliers and Consumer PRE • **P2:** Contract Upload • **P3:** Provision of Decomposition of Facility to T4M • **P4:** Technical Requision validation, Technical Requisition grant of access to providers, CIM Creation • **IP1:** Approve interactions of PRE with Providers, Approve of update of CIM • **P5:** Reception of PIM • **IP2:** Select Provider to issue a Purchase Order • **P6:** Approve Purchase Order, Approve PDRL, Grant access to selected supplier, revoke access to all other suppliers, Validate update of CIM • **IP3:** Approve interactions of PRE with Providers

ID	Organization / Role / Description	T4M Role
	responsible for the commercial issues	• **P7:** Reception of PIM with appended Documentation • **IP4:** Approve interactions of PRE with Providers • **P8:** Approve Frozen PIM • **P9:** Approve interactions of PRE with Providers • **CCP:** Initiate a Change Control Process, evaluate a Change Request, Approve a Variation Order • **IP5:** Update the Change Request
VN3UR2	**Organization** AIBEL **Role** Package Responsible Engineer (PRE) **Description** The PRE is the single point of contact from AIBEL towards the supplier(s) on technical issues for the overall process.	• **P3:** Creation of Decomposition of Facility • **P4:** Technical Requision CIM generation • **IP1:** Interact with Providers' PRE, Update of Technical Requisition CIM • **P5:** Reception of Tender PIM • **P6:** Generate Purchase Order / Update CIM with PDRL • **IP3:** Interact with Providers' PRE • **P7:** Reception of PIM with appended documentation • **IP4:** Interact with Providers' PRE • **P9:** Interact with Providers' PRE • **CCP:** Generate a Variation Order
VN3UR3	**Organization** Provider **Role** Package Responsible Engineer (PRE) **Description** The PRE is the single point of contact from Provider towards the Customer on technical issues for the overall process.	• **P1:** Supplier Sign/up, Access reception from Consumer PRB • **P4:** Technical Requision CIM reception • **IP1:** Interact with Consumer PRE, Reception of updated Technical Requisition CIM • **P5:** Generation of Tender PIM, Submitting of Tender PIM • **IP2:** Interact with Consumer PRE • **P6:** Reception of Purchase Order and PDRL CIM • **IP3:** Interact with Consumer PRE • **P7:** Generation of PIM with appended Documentation, Submitting of Documentation PIM • **IP4:** Interact with Consumer PRE • **P8:** Generation of PIM with Frozen Product information • **P9:** Interact with Consumer PRE • **CCP:** Initiate a Change Control Process, Evaluate a Change Request

5.3 As-Is Documents exchanged To-Be Information Models

In this section we describe the documents that will be used in the context of this value network and will be transformed into the Information Models that the T4M will utilize in order to facilitate a seamless interaction between the Consumer and the Provider(s). These information models are developed through different engineering processes that are conducted internally.

Table 45: VN3 Information models - included data

ID	Name	Description	Included Data
VN3IM1	Consumer Information Model CIM	System information and technical requirements	• Compatibility Requirements • Security Requirements • Usability Requirements • Reliability, Availability and Maintainability • Regulatory Compliance • Compliance with Standards • Performance Requirements • Operational Requirements • Data and Information Management • Cost Considerations • Safety Considerations • Maintenance and Inspection • Warranty and Support • Installation and Site Conditions • Material Selection and Construction • Documentation and Information for Engineering • Documentation and Information for Operation • Testing and validation • Vendor independence • Best Engineering Practice and quality assurance. **Format:** AAS, ZIP (PDF, XLS, DOC, DEXPI, ZIP, AML, HTML, etc.)
VN3IM2	Provider Information Model (PIM)	Product information and system requirements	• Design and operation information • Schedules and plans • Quality Plan • Procedures • Tables, Lists and Indexes • Certificates • Data sheets • Drawings • Diagrams • Isometrics • Instructions • Technical reports • Analysis • Calculations and curves • Checklists • Real Manufacturer standard documentation

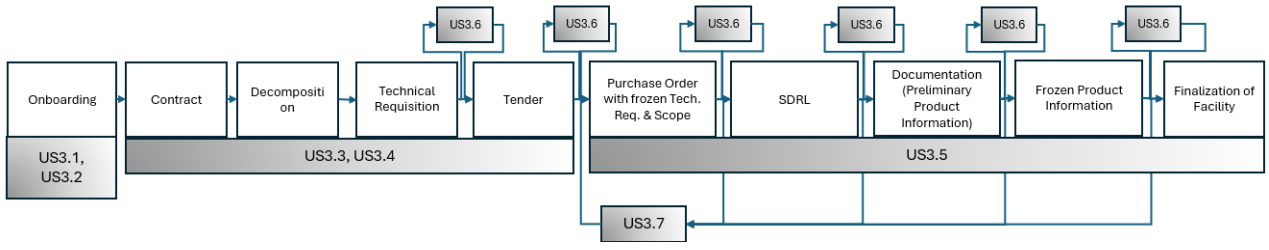
ID	Name	Description	Included Data
			• Declarations • DISPATCH DOSSIER • Spare Parts List and Interchangeability Record (SPIR) • Manufacturing Record Books • 3D Model **Format:** AAS, ZIP (PDF, XLS, DOC, STEP, ZIP, etc.)

5.4 User Stories

In this section, we present the user stories (USs) that were collected and validated through various rounds of VN3 interviews and workshops with the industrial partners of this VN. All USs include the involved user roles, their objective, and the reason why this objective is important.

Table 46: VN3 User Stories

ID	Description
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.
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.
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
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.
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
US3.6	As a Consumer PRB/PRE – Provider PRE want to interact (question, answer, annotate, etc.) on Information Models in order to be able to save time and avoid errors
US3.7	As a Consumer PRB/PRE – Provider PRE want to Initiate a Change Control Process in order to evaluate an identified needed change in the equipment packages



5.5 User Requirements

In this section, we present the user requirements in the form of use cases (UCs) where the pre-conditions, UC steps, and post-conditions are defined. This is followed by a UML diagram where the involved actors (human roles or systems) are depicted. These UCs are extracted from the USs presented in the previous section.

US3.1

Description: *As a Consumer / Provider I want to sign up/register my organization to the T4M platform to enable Manufacturing as a Service procurement of equipment packages.*

This user story is based on a main use case i.e., UC3.1: Register Value Network Organizations.

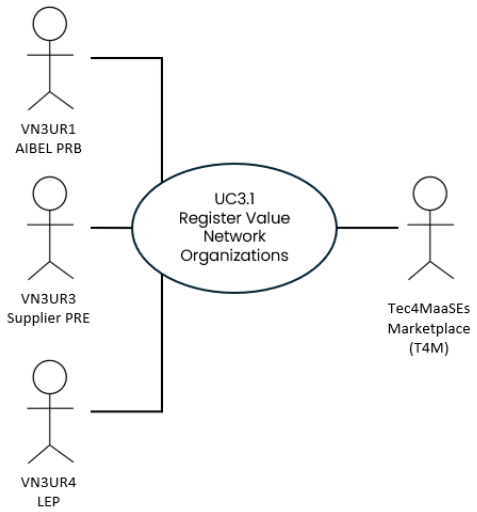


Figure 40: VN3 Use Case diagram for US3.1

Table 47: VN3 Description of UC3.1

UC3.1	Register Value Network Organizations
Brief Description	This use case outlines the actions taken to register a new company as a Consumer / Provider by providing company's general information and provisioning the initial contract upon which the manufacturing services that are being offered on a manufacturing as a service basis will be based upon.
Initiation	On demand when a new company wants to be registered in T4M as a Consumer / Provider.
Primary Actors	1. User: Consumer PRB, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. Consumer PRB, Provider PRE must be logged in.
	2. Internet connection is available.
Post-conditions	1. Company is registered as Consumer / Provider
	2. Granting access process is initiated.
Basic Flow	1. Consumer PRB, Provider PRE accesses the "Company's (Provider / Consumer) Area to register the company as a Consumer / Provider.
	2. T4M provides a wizard to include the information required to get specific details about the company and the acknowledgment of an NDA to ensure the confidentiality of any information from the other value network partners to which it may have access.
	3. Consumer PRB, Provider PRE completes the required information and submits

UC3.1	Register Value Network Organizations
	4. T4M checks that the mandatory information has been completed.
Alternative Flow(s)	At step 2, If Consumer PRB, Provider PRE has not completed all the mandatory information T4M informs that he/she needs to complete all required information before submitting it.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

US3.2

Description: *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.*

This user story is based on a main use case i.e., UC.3.2: Grant / Revoke data access.

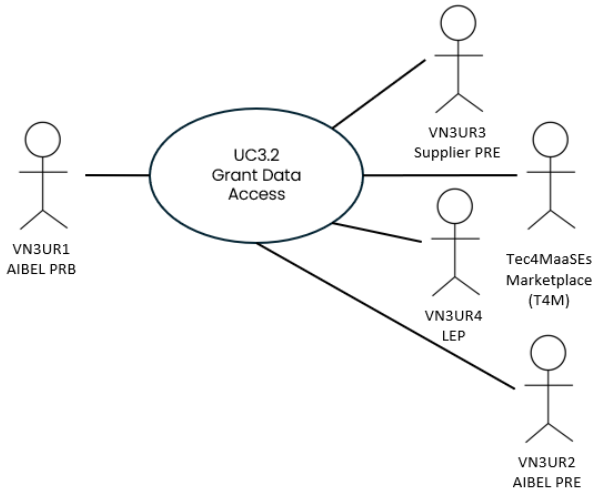


Figure 41: VN3 Use Case diagram for US3.2

Table 48: VN3 Description of UC3.2

UC3.2	Grant / Revoke Data Access
Brief Description	This use case outlines the actions taken to grant (or revoke) access to different stakeholders in the value network and for different assets.
Initiation	On demand when a Consumer PRB (or Provider PRE) wants to grant access to a specific asset and describe usage policies.
Primary Actors	1. User: Consumer PRB, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB) granting /revoking access must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
Post-conditions	Users have been granted access (or access has been revoked) to various assets in the scope of the value network
Basic Flow	1. Consumer PRB / Provider PRE accesses the "User's Area to Grant / Revoke access"
	2. T4M provides a list of companies in the value network
	3. Consumer PRB selects a company to grant access to
	4. T4M provides a list of users in the selected company

UC3.2	Grant / Revoke Data Access
	5. Consumer PRB selects a specific user to grant access to
	6. T4M provides a list of available assets upon which access will be granted to selected user
	7. Consumer PRB selects one or more assets from a list of assets (CIM, PIM)
	8. Consumer PRB submits the Grant Access
	9. T4M grants access to the specific asset (or assets) to the respective users
	10. T4M informs users (Consumer PRE, Provider PRE) of their new access rights
Alternative Flow(s)	At step 2, if Consumer PRB selects his/her own company, then T4M informs him/her that the other type of user he/she can grant access to is the Consumer PRE and (s)he proceeds to select him/her.
	At step 6 if Provider PRE is logged in then the list contains the PIM and access can be provided to Consumer PRB.
	At step 7, if there are one or more assets selected the Consumer PRB can un-select them, thus revoking the access to the specific asset and for the specific user
	If a system error occurs, a message is displayed to the user, explaining what went wrong.

US3.3

Description: *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*

This user story is based on the following use cases

- UC3.3: Information Model Creation
- UC3.4: Information Model Update

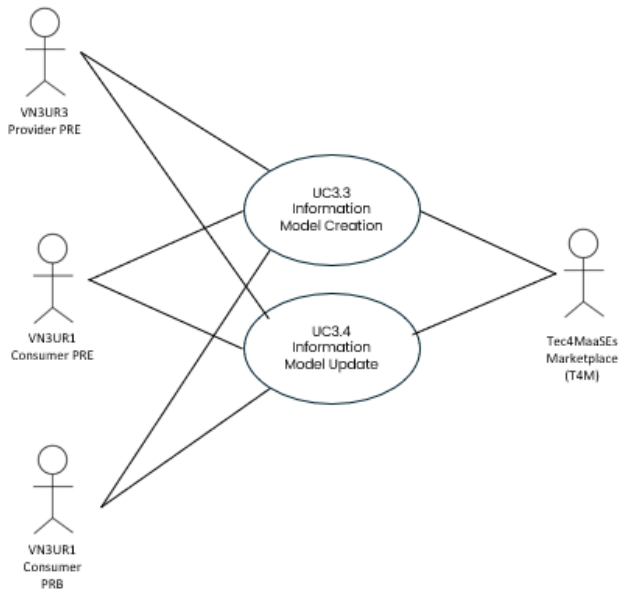


Figure 42: VN3 Use Case diagram for US3.3

Table 49: VN3 Description of UC3.3

UC3.3	Information Model Creation
Brief Description	This use case outlines the actions taken to create a new Asset (e.g. Information Model) to be used in the scope of the new facility production at specific phases of the overall process within the scope of T4M Marketplace.
Initiation	On demand when a Consumer PRE (or Provider PRE) wants to create a new asset (i.e., Consumer Information Model – CIM for Consumers and Provider Information Model - PIM) to be used in the value network at different phases.
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered
	4. Users per Company in the value network are registered
Post-conditions	Consumer PRB / Consumer PRE / Provider PRE has generated a new Asset that is now available in T4M
Basic Flow	1. Consumer PRB / Consumer PRE / Provider PRE accesses the “Create New Asset”
	2. T4M provides a list of available Asset Types that can be generated as follows a. Consumer PRB, Consumer PRE: Consumer Information Model - CIM b. Provider PRE: Provider Information Model - PIM
	3. Consumer PRB - Provider PRE selects the Asset to be created
	4. Consumer PRB – Provider PRE provides the necessary details of the Information Model through uploading a file with the initial information of the specific IM with a specific T4M readable format.
	5. T4M creates the Asset and informs the user to grant access to the Asset from a list of available users eligible to receive access.
	6. Consumer PRB / Provider PRE selects the users
	7. T4M grants access to the selected users.
	8. T4M informs users (Consumer PRB / Consumer PRE / Provider PRE) of a successful New Asset creation
Alternative Flow(s)	At step 2, if T4M is unable to produce a list of available Asset Types it informs the user
	At step 3 if Asset is already available in the selected Asset Type, T4M informs the user that an asset of that type already exists and the user can select to either update the existing or do nothing
	At step 7, If the Asset is pre-existing the Consumer PRB / Provider PRE is presented with a list of users that already have access to it and the Consumer PRB / Provider PRE can de-select any user to revoke access to the Asset.
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 50: VN3 Description of UC3.4

UC3.4	Information Model Update
Brief Description	This use case outlines the actions taken to update an Information Model (CIM or PIM) to be enhanced and proceed across the different phases of the new facility construction.
Initiation	On demand when a Consumer PRE (or Provider PRE) wants to update the CIM or PIM
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace

UC3.4	Information Model Update
Pre-conditions	1. User (Consumer PRE, Provider PRE) must be logged in.
	2. CIM or PIM must be available
	3. Users must have been granted access to the respective CIM or PIM they wish to update
Post-conditions	CIM or PIM are updated having additional information and different status according to the phase of the project
Basic Flow	1. Consumer PRB / Consumer PRE / Provider PRE accesses the "View Information Model"
	2. T4M provides a list of available Information Models the user has access to
	3. Consumer PRB - Provider PRE selects the IM to be updated
	4. Consumer PRB – Provider PRE provides the necessary details of updated of the Information Model through a. Selecting the phase of the IM b. Appending information on the IM (manually or via a file formatted in T4M readable manner)
	5. T4M updates the IM and informs the users that have access to it on the given update
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

US3.4

Description: *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.*

This user story is based on the following use cases

- UC3.4.1: Upload of the Contract to develop a new facility
- UC3.4.2: Facility Decomposition provision to T4M
- UC3.4.3: Technical Requisition creation and issuing to selected Suppliers (Consumer Information Model CIM)
- UC3.4.4: Tender Reception and Evaluation (Provider Information Model PIM)

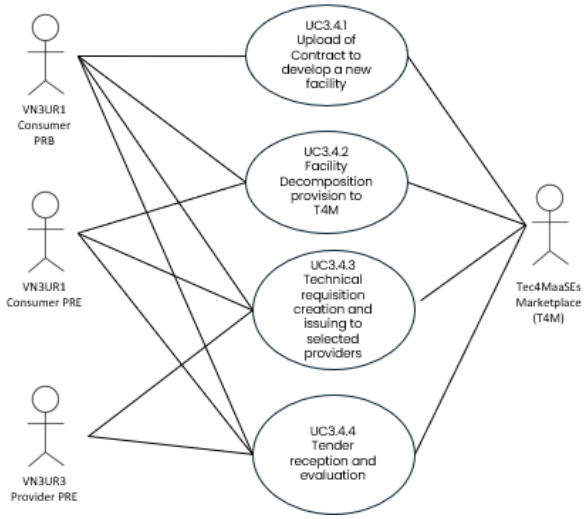


Figure 43: VN3 Use Case diagram for US3.4.1

Table 51: VN3 Description of UC3.4.1

UC3.4.1	Upload of the Contract to develop a new facility
Brief Description	This use case outlines the actions taken to upload the contract to develop a new facility that will be used to link CIMs and PIMs until the provision of the facility.
Initiation	On demand when a Consumer PRB is assigned a new project from the Large Energy Producer
Primary Actors	1. User: Consumer PRB 2. System: T4M Marketplace
Pre-conditions	User (Consumer PRB) must be logged in.
Post-conditions	Consumer PRB has uploaded the contract and the new facility development is initiated
Basic Flow	1. Consumer PRB provides T4M the Contract 2. Consumer selects Validate Contract 3. T4M informs Consumer PRB (s)he can initiate the new facility development
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 52: VN3 Description of UC3.4.2

UC3.4.2	Facility Decomposition provision to T4M
Brief Description	This use case outlines the actions taken by Consumer PRE and Consumer PRB to provide the Facility Decomposition to T4M towards initiating the different phases of the process to develop the facility.
Initiation	On demand when a Consumer PRB is assigned a new project from the Large Energy Producer and has a validated contract.
Primary Actors	1. User: Consumer PRB, Provider PRE 2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE) must be logged in. 2. Internet connection is available. 3. Companies in the value network are registered. 4. Users per Company in the value network are registered 5. UC3.4.1 has been successfully completed
Post-conditions	1. T4M has the full set of components / sub-components of the equipment packages that will be procured 2. Technical Requisition Phase can be initiated
Basic Flow	1. Consumer PRB grants access to the new facility project development to Consumer PRE (UC.3.2) 2. T4M informs Consumer PRE to develop the Facility Decomposition 3. Consumer PRE enters “Facility Decomposition” area in T4M 4. Consumer PRE selects “Add a new Equipment Package” 5. T4M presents Consumer PRE with input fields to introduce information relevant to the new system 6. Consumer PRE enters information and creates the new system. 7. Consumer PRE selects “Add a new equipment package” 8. T4M presents Consumer PRE with input fields to introduce information relevant to the new equipment package (AIBEL complete what info is needed for a new equipment package) 9. Consumer PRE selects “Finished Decomposition of Facility” 10. T4M presents a list of all registered Systems / Equipment packages to Consumer PRE

UC3.4.2	Facility Decomposition provision to T4M
	11. Consumer PRE selects “Issue facility decomposition to PRB”
	12. T4M informs Consumer PRB to review and validate the Facility Decomposition
	13. Consumer PRB selects “Validate facility decomposition”
	14. T4M informs PRE that all systems / equipment packages are validated and Technical Requisition phase can begin.
Alternative Flow(s)	In Step 11 Consumer PRE can select “Update” to edit information on any equipment package
	In Step 11 Consumer PRE can select “Delete” to delete any equipment package
	In Step 14 Consumer PRB can select “Request revision” to receive a revision from the Consumer PRE. T4M notifies Consumer PRE to update information on the specific equipment packages. Upon update Consumer PRE proceeds with Step 10
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 53: VN3 Description of UC3.4.3

UC3.4.3	Technical Requision creation and issuing to selected Suppliers Consumer Information Model - CIM
Brief Description	This use case outlines the actions taken by Consumer PRE and Consumer PRB to prepare and release a Technical Requisition for each component package in the Facility Decomposition towards receiving Tenders as well as the role of Provider PRE in the process.
Initiation	On demand when a Consumer PRB initiates the phase of enquiry (Technical Requisition).
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. UC3.4.2 have been successfully completed
Post-conditions	1. The Consumer Information Model (CIM) is populated and available, one for each equipment package
	2. Selected Suppliers are granted access to one or more CIM(s)
	3. Tender reception and evaluation (UC3.4.4) phase can be initiated.
Basic Flow	1. Consumer PRB grants access to the Technical Requisition Area to Consumer PRE
	2. T4M informs Consumer PRE to develop one Technical Requisition IM per equipment package
	3. Consumer PRE enters “Technical Requisition” area in T4M
	4. T4M presents the list of all registered Systems / Equipment packages to Consumer PRE
	5. Consumer PRE selects “Create CIM” for any equipment package a. UC.3.3 is initiated for the specific asset
	6. Consumer PRE selects “CIM of Technical Requisition Phase Developed”
	7. T4M informs Consumer PRB to review and validate the Technical Requisition phase CIMs
	8. Consumer PRB selects “Validate” for each equipment package
	9. T4M informs Consumer PRE that all systems / equipment packages are validated and Enquiry phase can begin.
	10. Consumer PRB accesses “Enquiry” area in T4M

UC3.4.3	Technical Requision creation and issuing to selected Suppliers Consumer Information Model - CIM
	11. T4M presents Consumer PRB with a list of all validated equipment package
	12. Consumer PRB selects “Select Provider” on any equipment package
	13. T4M presents Consumer PRB with a list of Providers where (s)he can select for each equipment package 1+ suppliers to grant access to the CIM of the Technical Requisition Phase.
	14. Consumer PRB selects providers for each equipment package
	15. Consumer PRB selects “Issue Enquiry”
	16. T4M grants access for each “CIM” to selected providers’ PRE(s)
	17. T4M notifies Providers PRE(s) for their access on respective IMs
	18. T4M initiates the Tender reception phase (UC3.4.4)
Alternative Flow(s)	In Step 6 T4M validates that all equipment packages have a respective Technical Requisition IM. If false, T4M informs Consumer PRB and PRE of the missing IM(s)
	In all steps if the Consumer PRB or Provider PRE needs additional information T4M initiates US3.6
	In Step 15 T4M validates that all equipment packages have at least 1 Supplier binned to them. If false, T4M informs Consumer PRB and PRE of the missing Supplier on the IM(s)
	If a system error occurs, a message is displayed to the user, explaining what went wrong.

Table 54: VN3 Description of UC3.4.4

UC3.4.4	Tender Reception and Evaluation Provider Information Model - PIM
Brief Description	This use case outlines the actions taken by (a) the Provider PRE to accept an Enquiry, (b) Prepare a PIM of Tender, (c) Submit a PIM and the Consumer PRB to evaluate a Tender Towards initiating the US3.5.
Initiation	On demand when a Consumer PRB finishes the phase of Enquiry UC.3.4.4 Step 18.
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. UC3.3, UC3.4.2 and UC3.4.3 have been successfully completed
Post-conditions	1. The Provider Information Model – PIM is available, one for each equipment package
	2. A Provider is selected for Issuing a Purchase Order (PO) per equipment package
	3. US3.5 can initiate
Basic Flow	1. Provider PRE enters “Tenders” area in T4M
	2. T4M presents the list of all Inquiries (and associated CIMs) they are granted access to.
	3. Provider PRE selects “Create Provider Information Model” for a specific CIM a. UC3.3 is initiated for the specific Information Model
	4. Provider PRE selects “PIM developed” for the selected
	5. Provider PRE selects “Issue PIM”
	6. T4M provides access to Consumer PRB to the PIM
	7. T4M informs Consumer PRB / Consumer PRE to review and evaluate the submitted

UC3.4.4	Tender Reception and Evaluation Provider Information Model - PIM
	offer through the PIM
	8. Consumer PRB / PRE enters “Tender” area and selects the specific PIM from a list of CIM-PIMs’ submissions
	9. US3.5 is initiated for this specific IM
	10. T4M informs users (Consumer PRE, Provider PRE) of their new access rights
Alternative Flow(s)	In Step #5 if missing pieces of information exist in the PIM, T4M informs Provider PRE of the missing information
	In all steps if the Consumer PRB or Provider PRE needs additional information T4M initiates US3.6
	If a system error occurs, a message is displayed to the user, explaining what went wrong.

US3.5

Description: *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. This user story is based on the following use cases.*

- UC3.5.1: Issue CIM with appended information of Purchase Order and PDRL Phase
- UC3.5.2: Issue PIM with appended information of Documentation
- UC3.5.3: Issue PIM with appended information of Frozen Product Information
- UC3.5.4: Finalization of Service Provision

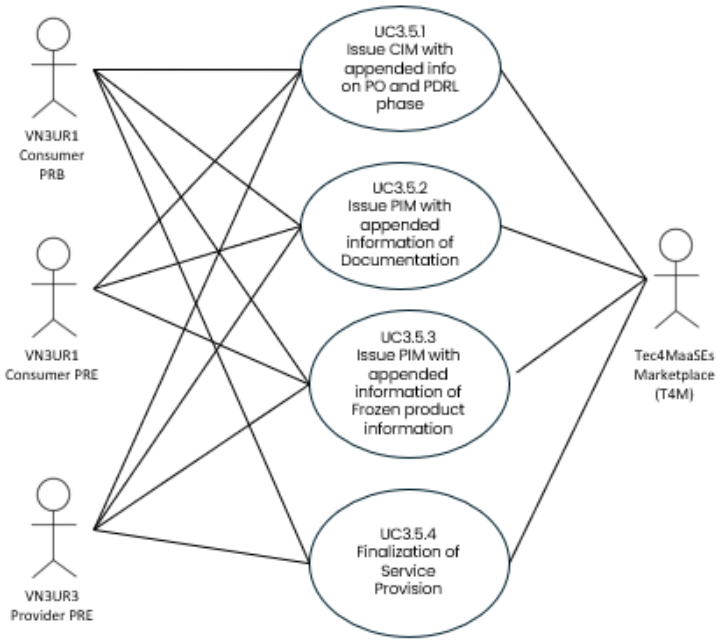


Figure 44: VN3 Use Case diagram for US3.5

Table 55: VN3 Description of UC3.5.1

UC3.5.1	Issue CIM with appended information of Purchase Order and PDRL Phase
Brief Description	This use case outlines the actions taken by (a) the Consumer PRB and PRE to issue a Purchase Order (PO) and the PDRL, and the (b) Provider PRE to accept them through the Consumer

UC3.5.1	Issue CIM with appended information of Purchase Order and PDRL Phase
	Information Model – CIM [Purchase Order Phase], towards enabling monitoring of the status of the new facility development in the particular phase.
Initiation	On demand when a Consumer PRB finishes the phase evaluation of Tenders.
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: Tec4MaaSEs Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. US3.4 has been successfully completed and all equipment packages have a selected supplier to be provided by
Post-conditions	1. A set of CIMs are available, one for each equipment package and associated with the PIM
	2. The Provider PREs have access to CIMs of Purchase Order and PDRL.
	3. All Provider PREs without a Purchase Order have their access revoked and do not proceed onward
Basic Flow	1. Consumer PRE enters “Purchase Orders” area in T4M
	2. T4M presents the list of all Technical Requisition IMs and associated Tender IMs
	3. Provider PRE selects “Create Purchase Order CIM” for each PIM a. UC3.4 is initiated for the specific asset
	4. Consumer PRE selects “CIM with Purchase Order and PDRL Developed”
	5. T4M informs Consumer PRB about the completion of the creation of all Purchase Order CIMs from Consumer PRE
	6. Consumer PRB selects Issue CIM to selected provider
	7. T4M informs Consumer PRB / Consumer PRE and Provider PRE that Purchase Order CIM is issued
	8. T4M initiates the UC3.5.2
Alternative Flow(s)	In Step #4 if missing pieces of information exist in the CIM, T4M informs Consumer PRE of the missing information
	In all steps if the Consumer PRB, Provider PRE needs additional information T4M initiates US3.6 on the specific Information Model
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 56: VN3 Description of UC3.5.2

UC3.5.2	Issue PIM with appended information of Documentation
Brief Description	This use case outlines the actions taken by (a) the Provider PRE to issue the Documentation with preliminary product information on the PIM and the consumer PRE to accept them, towards enabling monitoring of the status of the new facility development in the particular phase.
Initiation	On demand when a Consumer PRB finishes the phase of Issue of Purchase Order.
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.

UC3.5.2	Issue PIM with appended information of Documentation
	4. Users per Company in the value network are registered
	5. US3.4 has been successfully completed and all equipment packages have a selected supplier to be provided by
Post-conditions	1. A set of PIMs with appended Documentation are available, one for each equipment package
	2. The Provider PRE, Consumer PRB, Provider PRE have access to PIM with Documentation
Basic Flow	1. Provider PRE enters “Documentation” area in T4M
	2. T4M presents the list of all Technical Requisition CIMs with associated Purchase Order CIMs
	3. Provider PRE selects “Provide Documentation” for each CIM a. UC3.4 is initiated for the specific asset (PIM) in this phase
	4. Provider PRE selects “Documentation appended” in PIM
	5. T4M informs Consumer PRB, Consumer PRE about the completion of the update of the PIM with Documentation from Provider PRE
	6. Consumer PRE enters “Documentation” area in T4M
	7. T4M presents the Consumer PRB with the list of PIMs with Documentation
	8. Consumer PRB validates the PIMs with Documentation
	9. T4M informs Consumer PRB / Consumer PRE and Provider PRE that selected PIM with Documentation is accepted
	10. T4M initiates the UC3.5.3
Alternative Flow(s)	In Step #4 if missing pieces of information exist in the PIM, T4M informs Provider PRE of the missing information
	In all steps if the Consumer PRB, Provider PRE needs additional information T4M initiates US3.6
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 57: VN3 Description of UC3.5.3

UC3.5.3	Issue PIM with appended information of Frozen Product Information
Brief Description	This use case outlines the actions taken by (a) the Provider PRE to issue the Frozen Product Information in the PIM, the Consumer PRE to accept them, towards enabling monitoring of the status of the new facility development in the particular phase.
Initiation	On demand when a Consumer PRB finishes the phase Issue of Documentation by validating the received PIM.
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. US3.4 has been successfully completed and all equipment packages have a selected supplier to be provided by
Post-conditions	1. A set of the Frozen Product Information is appended to the PIM for each equipment package
	2. The Provider PRE, Consumer PRB and PRE have access to the Frozen Product

UC3.5.3	Issue PIM with appended information of Frozen Product Information
	Information- stage PIM
Basic Flow	3. Provider PRE enters “Frozen Product Information” area in T4M
	4. T4M presents the list of all PIMs
	5. Provider PRE selects “Append Frozen Product Information” for a PIM a. UC3.4 is initiated for the specific Information Model
	6. Provider PRE selects “Frozen Product Information appended” on PIM
	7. T4M informs Consumer PRB and Consumer PRE about the completion of the appending of the Frozen Product Information to the PIM from Provider PRE
	8. Consumer PRB/PRE enters “Frozen product Information” area in T4M
	9. T4M informs Consumer PRB/PRE of the list of PIMs with Frozen Product Information
	10. Consumer PRB validates the PIM with Frozen Product Information
	11. T4M informs Consumer PRB / PRE and Provider PRE that PIM with Frozen Product Information is accepted
	12. T4M initiates the UC3.5.4
Alternative Flow(s)	In Step #5 if missing pieces of information exist in the Frozen Product Information of the PIM, T4M informs Provider PRE of the missing information
	In all steps if the Consumer PRB, or Provider PRE needs additional information T4M initiates US3.6
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 58: VN3 Description of UC3.5.4

UC3.5.4	Finalization of Service Provision
Brief Description	This use case outlines the actions taken by the Consumer PRB to finalize the service provision after a facility is developed.
Initiation	On demand when a Consumer PRB Enters the Service Finalization Area and Initiates the process.
Primary Actors	1. User: Consumer PRB, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. Guarantee period has passed
Post-conditions	1. Project has been successfully finalized
Basic Flow	1. Consumer PRB enters “Service Finalization” area in T4M
	2. T4M presents the list of all Contracts with associated CIMs and PIMs
	3. Consumer PRB validates the appropriate operation of each equipment package
	4. T4M Provider PRE that equipment package is validated
	5. T4M Informs Consumer PRB, Provider PRE for project completion
Alternative Flow(s)	In all steps until guarantee period reached if the Consumer PRB or Provider PRE needs additional information T4M initiates US3.6
	If a system error occurs, a message is displayed to Consumer PRB / Provider PRE explaining what went wrong.

US3.6

Description: *As a Consumer PRB/PRE – Provider PRE want to interact (question, answer, annotate, etc.) on Information Models in order to be able to save time and avoid errors*

This user story is based on the following use cases

- UC3.6.1: Provide a Comment to an IM
- UC3.6.2: View a Comment to an IM
- UC3.6.3: Resolve a Comment to an IM

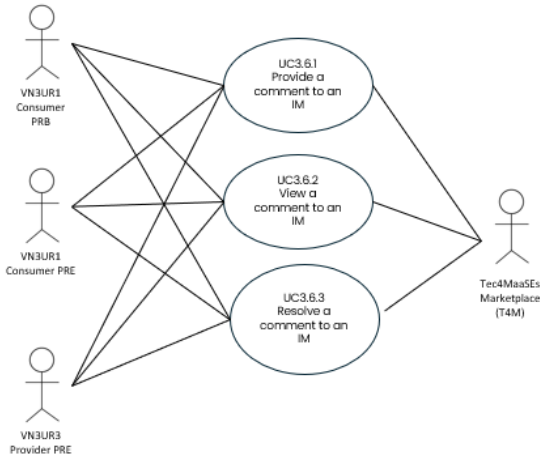


Figure 45: VN3 Use Case diagram for US3.6

Table 59: VN3 Description of UC3.6.1

UC3.6.1	Provide a comment to an IM segment
Brief Description	This use case outlines the actions taken by the Consumer PRB / Consumer PRE or Provider PRE to annotate a specific Information Model in a specific part towards informing all involved stakeholders about a new comment (or general information piece) (s)he has introduced.
Initiation	On demand when a Consumer PRB / PRE or a Provider PRE enters the Interactions Area and Initiates the process.
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. The IM upon which a comment is to be provided is available in T4M
Post-conditions	1. A specific segment of an Information Model has been annotated with a comment
Basic Flow	1. Consumer PRB / Consumer PRE or Provider PRE enters “Discussions” area in T4M
	2. T4M presents the list of all PIMs that the user has access to
	3. User selects “Add Comment” to any Information Model from the available.
	4. T4M presents the user with the contents of the IM
	5. User selects a segment

UC3.6.1	Provide a comment to an IM segment
	6. T4M presents an entry field
	7. User inserts comment
	8. T4M logs Comment, Recipient(s), IM, IM segment
	9. T4M informs all remaining users with access to the respective IM of a new comment
Alternative Flow(s)	In step 7 user can indicate target recipient of comment by utilizing @CPRB @CPRE @SPRE
	In step 7 if user issuing comment is Consumer PRE a sub process is imitated as follows: 1. T4M informs Consumer PRB, Consumer PRE wants to issue a comment 2. Consumer PRB validates the comment 3. T4M proceeds to Step 8
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 60: VN3 Description of UC3.6.2

UC3.6.2	View a comment to an IM segment
Brief Description	This use case outlines the actions taken by the Consumer PRB / Consumer PRE or Provider PRE to examine the comments / annotation of a specific Information Model in a specific segment.
Initiation	On demand when a Consumer PRB / PRE or Provider PRE enters the Interactions Area and Initiates the process.
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. The IM upon which a comment is to be provided is available in T4M
	6. Users have access to IM
Post-conditions	A specific annotation / or set of sequential annotations on a segment of an IM is presented to the user
Basic Flow	1. Consumer PRB / Consumer PRE or Provider PRE enters “Discussions” area in T4M
	2. T4M presents the list of all IMs that the user has access to
	3. User selects “View Comments” to any Information Model from the available.
	4. T4M presents the user with the contents of the IM, where comments exist
	5. User selects a segment
	6. T4M presents the series of comments binned to the specific segment from all users
	7. User initiates UC3.6.1 if s(he) wants to respond
Alternative Flow(s)	In Step 7 a user may exit the comment view pane and return to the Discussions area
	If a system error occurs, a message is displayed to Consumer PRB / Consumer PRE / Provider PRE explaining what went wrong.

Table 61: VN3 Description of UC3.6.3

UC3.6.3	Resolve a comment to an IM segment
Brief Description	This use case outlines the actions taken by the Consumer PRB to resolve a comment (or a thread) of a specific Information Model in a specific segment.
Initiation	On demand when a Consumer PRB enters the Interactions Area and Initiates the process

UC3.6.3	Resolve a comment to an IM segment
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. The IM upon which a comment is to be provided is available in T4M
	6. Users have access to IM
Post-conditions	A specific annotation / or set of sequential annotations on a segment of an IM is resolved
Basic Flow	1. Consumer PRB enters “Discussions” area in T4M
	2. T4M presents the list of all IMs
	3. Consumer PRB selects “View Comments” to any Information Model from the available.
	4. T4M presents the user with the contents of the IM, where comments exist
	5. Consumer PRB selects a segment
	6. T4M presents the series of comments binned to the specific segment from all users
	7. Consumer PRB selects “Resolve Thread”
	8. T4M present user with input field of “Reason of Resolution”, “Effective from”, “Need for an IM Update”
	9. Consumer PRB fills all fields.
	10. T4M informs Consumer PRE, and Provider PRE of decision of resolution
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

US3.7

Description: *As a Consumer PRB/PRE – Provider PRE want to Initiate a Change Control Process in order to evaluate an identified needed change in the equipment packages*

This user story is based on the following use cases

- UC3.7.1: Initiate Change Request
- UC3.7.2: Joint Evaluation of Change Request and adjustments
- UC3.7.3: Creation of Variation Order and Update of CIM phase Purchase Order

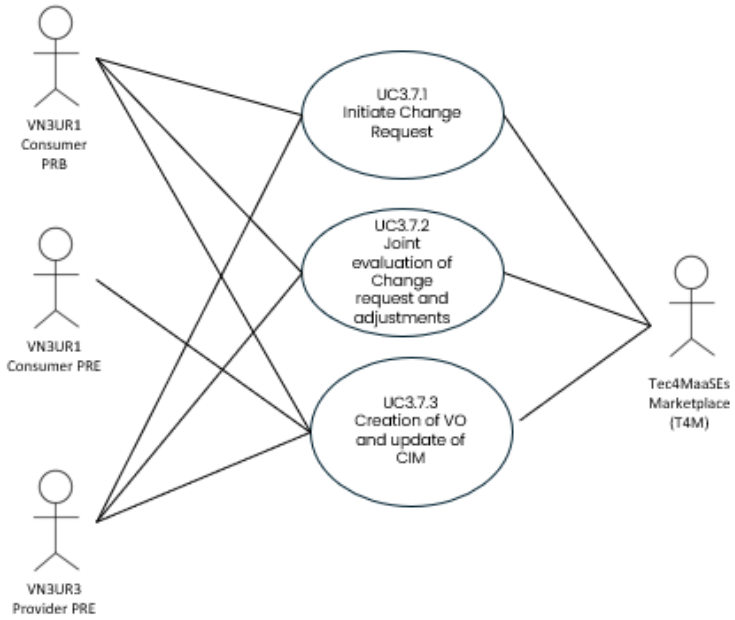


Figure 46: VN3 Use Case diagram for US3.7

Table 62: VN3 Description of UC3.7.1

UC3.7.1	Initiation of Change Request
Brief Description	This use case outlines the actions taken by the Consumer PRB or Provider PRE to initiate a change request toward updating a CIM.
Initiation	On demand when a Consumer PRB or PRE or Provider PRE enters the Change Request Area and Initiates the process.
Primary Actors	1. User: Consumer PRB, Consumer PRE, Provider PRE
	2. System: Tec4MaaSEs Marketplace
Pre-conditions	1. User (Consumer PRB, Consumer PRE, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. The IM upon which a change request is initiated is available in T4M
	6. Users have access to IM
Post-conditions	A Change Request has been issued with all necessary information to be jointly evaluated
Basic Flow	1. Consumer PRB / Consumer PRE or Provider PRE enters “Change Control Process” area in T4M
	2. T4M presents the list of all IMs in their most recent phase that the user has access to
	3. User selects “Change Control Process” to any Information Model from the available
	4. T4M presents the user with the contents of the IM
	5. User selects a segment
	6. T4M presents an entry field
	7. User inserts Reason behind Change Control Process Request and accompanying information
	8. T4M logs Comment, Recipient(s), IM, IM segment
	9. T4M informs all remaining users with access to the respective IM of a new Change Request.

UC3.7.1	Initiation of Change Request
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 63: VN3 Description of UC3.7.2

UC3.7.2	Joint Evaluation of Change Request and Adjustments
Brief Description	This use case outlines the actions taken by the Consumer PRB and Provider PRE to jointly evaluate a Change Request.
Initiation	On demand when a Consumer PRB or Provider PRE enters the Change Request Area and an active Change Request is available for evaluation.
Primary Actors	1. User: Consumer PRB, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Provider PRE) must be logged in.
	2. Internet connection is available.
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. The IM upon which a comment is to be provided is available in T4M
	6. Users have access to IM
Post-conditions	An Adjusted Change Request has been issued with all necessary information to be jointly evaluated.
Basic Flow	1. Consumer PRB or Provider PRE enters “Change Control Process” area in T4M
	2. T4M presents the list of all IMs that the user has access to and have an active change request
	3. User selects “Evaluate active changes” to any Information Model form the available.
	4. T4M presents the user with the contents of the change request
	5. User Evaluates change request
	6. User Inserts accompanying information for their evaluation
	7. T4M logs Evaluation result, Information
	8. T4M informs all remaining users with access to the respective IM of a new Evaluation.
Alternative Flow(s)	If in step #5 User Evaluates negatively the Change Request, T4M marks step 6 as Adjustment proposal
	In Step 8 if after (1-5) adjustments on joint positive evaluation if produced from all users, Change Control Process terminates and all IM remain as are
	In Step 8 if all users have evaluated positively the Change Request, then UC3.7.3 is initiated by T4M System
	If a system error occurs, a message is displayed to the user explaining what went wrong.

Table 64: VN3 Description of UC3.7.3

UC3.7.3	Creation of Variation Order and Update of CIM
Brief Description	This use case outlines the actions taken by the Consumer PRB to issue a Variation Order (VO) and update the Consumer Information Model.
Initiation	Automatically when a change request is evaluated positively by all participants.
Primary Actors	1. User: Consumer PRB, Provider PRE
	2. System: T4M Marketplace
Pre-conditions	1. User (Consumer PRB, Provider PRE) must be logged in.
	2. Internet connection is available.

UC3.7.3	Creation of Variation Order and Update of CIM
	3. Companies in the value network are registered.
	4. Users per Company in the value network are registered
	5. A CIM is available in T4M
	6. Users have access to IM
	7. UC3.7.2 has finished with a positive evaluation on the specific IM
Post-conditions	1. A Variation Order (VO) is developed
	2. The Consumer Information Model is updated
Basic Flow	1. Consumer PRB enters “Change Control Process” area in T4M
	2. T4M presents the list of all IMs with active change requests
	3. Consumer PRB selects “View Evaluated Change Requests” to any Information Model form the available.
	4. T4M presents the user with the contents of the evaluated change request
	5. Consumer PRB assigns Consumer PRE to update CIM a. PRE initiates UC3.4 for CIM update
	6. T4M informs all users that CIM is updated with Variation Order and requests Provider PRE to update related PIM
Alternative Flow(s)	If a system error occurs, a message is displayed to the user explaining what went wrong.

5.6 Existing systems and related user stories

In this section, we describe the existing systems that are involved in the development of the different Information Models (IMs) of VN3. As a core part of the T4M functionality is to enable automated import/export of the contents of the IMs to the different systems of the Consumer and the Supplier(s), the following systems were found to be needed to develop the Information Models after having conducted the related engineering work. All systems are mapped to a set of user stories, while a connection type and data eligible for impor /export is described for each system.

Note: As the formulation of all the Information Models falls under the PRE role, the users that are involved in all processes relevant to Information Models Generation (CIM, PIM) in the relevant USs are the Package Responsible Engineers of the Supplier and the Consumer. The systems from which the data will be produced are presented in the following table.

Table 65: VN3 Existing systems

Value Network Users	Existing Engineering System	Related US	Connection Type	Information Model
EPC Contractor **Consumer**	EIS – Engineering Information System		File transfer Format: AAS, ZIP (PDF, XLS, DOC, DEX-PI, ZIP, AML, HTML, etc.)	CIM
Supplier **Provider**	Engineering Information System		File transfer/export/import (Jt, .coJt)	PIM

5.7 KPIs, Calculation Methods and Base lines

In this section we describe the KPIs that will be used to assess the T4M tangible (measurable) impact of the VN3 pilot. The assessment involves the comparison of the as-is and the to-be situation. This comparison is based on specific KPIs which are defined in terms of (a) the objective that is required, (b) the baseline of the KPI (as-is situation) and (c) the target value of the KPI after the T4M implementation.

VN3-KPI-1: 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.
- Calculation description and function: 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 Center (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.
- Related Data: N/A
- Availability of data: Via interview of employees at the DCC and PREs
- Baseline: To be defined.
- Goal: To reduce the duration by 50% through the usage of standardized information packages and information models with machine understandable data.

VN3-KPI-2: 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
- Calculation description and function: 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 Center (DCC).
    - Duration of time from drawings and documents that are delivered to DCC until they are available for the supplier.
- Related Data: N/A
- Availability of data: Via interview of employees at the DCC and PREs
- Baseline: To be defined.
- Goal: To reduce the duration by 30% through the usage of standardized information packages and information models with machine understandable data.

VN3-KPI-3: 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.
- Calculation description and function: Count number of processes which are automated.
- Related Data: N/A

- Availability of data: Yes.
- Baseline: To be defined
- Goal: 5

VN3-KPI-4: Verification effort of comments and changes

- Definition: Time (in manhours) used by the PRE and other engineers to verify comments and changes
- Calculation description and function: Time (manhours) used by the PRE and other engineers to verify comments and changes
- Related Data: N/A
- Availability of data: Interview of PRE and relevant employees
- Baseline: To be defined
- Goal: To reduce verification time by 30%

6 Tec4MaaSEs Configuration and Access Requirements

6.1 Introduction

In the specific user stories (USs) and requirements outlined earlier, each value network (VN) expresses a desire to implement and utilize distinct functionalities. However, the fundamental essence of the Tec4MaaSEs (T4M) concept, as detailed in Section 2, remains consistent across all pilots. Additionally, there exists a universal functionality that is independent of any specific VN and pertains to the configuration of the T4M System.

This functionality encompasses the seamless and dynamic (re)-configuration of supply chains, along with essential capabilities for managing T4M users (roles and access rights) as well as the decomposition, matching and composition that constitute the core services of the T4M ecosystem.

These functionalities are universal across all VNs and are essential in ensuring that T4M can cater to the requirements of any organization looking to leverage its capabilities.

6.2 User Roles

In this section we present the involved user roles, entity roles that participate in configuring and accessing the T4M System. Considering that the corresponding user stories and use cases are pilot-agnostic, we distinguish the user roles with respect to system administration rights they should have. Thus, at this level of analysis we have two types of user roles, i.e., the Super-User acting as the T4M System administrator and the User which refers to a type of user without administrator privileges. The latter type of user could apply to all the roles identified in each pilot.

Table 66: T4M User Roles

Role	Description
Super-User	The system administrator
User	All types of users except super-user

6.3 System Configuration and Access User Stories

In this section we present the user stories that stem out as prerequisites from all the user stories collected for each pilot or define a common functionality that applies to all pilots. All user stories include the involved user roles, their objective and the reason why this objective is important. Since these apply to all pilots, we use a different number i.e., "x=0") to distinguish them from the pilot-specific user stories, i.e., we use the notation US0.y.

Table 67: T4M Access User Stories

ID	Description
US0.1	As a super-user I want to manage (create/update/delete) the users with respect to their roles and access rights because I need to provide different roles and access rights to different users.
US0.2	As a super-user I want to configure/update/remove a supply chain from the recommended list by T4M, because I need to fulfil the consumer's registered request for services.
US0.3	As a super-user I want to configure/update the disrupting events that might occur within the preferred supply chain by the consumer, because I need to have notifications whenever these events occur.
US0.4	As a user I want to access and manage (activate/update) my account because I need to make appropriate changes to my account details when needed.

6.4 System Configuration and Access User Requirements

In this section we present the user requirements in the form of use cases (UCs) where the pre-conditions, UC steps and post-conditions are defined. These UCs are extracted from the USs presented in the previous section.

US0.1

Description: *As a super-user I want to manage (create/update/delete) the users with respect to their roles and access rights because I need to provide different roles and access rights to different users.*

This user story is composed of six use cases:

- Create User Role: Describes the actions required to create a User Role.
- Update User Role: Describes the actions required to update a User Role.
- Delete User Role: Describes the actions required to delete a User Role.
- Create User: Describes the actions required to create a new user.
- Update User: Describes the actions required to update an existing user.
- Delete User: Describes the actions required to delete an existing user.

Table 68. Description of UC0.1.1

UC0.1.1	Create User Role
Brief Description	This use case states the actions taken to create a new user role.
Primary Actors	Super-User
Pre-conditions	Super-User must be authenticated.
Post-conditions	A new user role is created with access rights set by the Super-User.
Basic Flow	1. The Super-User edits the new user role information (name, access rights).
	2. The new user role is stored in the System.
Alternative Flow(s)	If an error occurs, a message is displayed to the Super-User explaining what went wrong.

Table 69. Description of UC0.1.2

UC0.1.2	Update User Role
Brief Description	This use case states the actions taken to update an existing user role.
Primary Actors	Super-User
Pre-conditions	1. Super-User must be authenticated.
	2. User roles must be configured through UC0.1.1.
Post-conditions	An existing user role is updated with new access rights set by the Super-User.
Basic Flow	1. The System retrieves all the existing User roles with their access rights and displays them.
	2. The Super-User edits the information (name, access rights) of the user role that will be used.
	3. The Super-User selects to store the updated information of the existing user role.
	4. The System stores the updated information.
Alternative Flow(s)	If an error occurs, a message is displayed to the Super-User explaining what went wrong.

Table 70. Description of UC0.1.3

UC0.1.3	Delete User Role
Brief Description	This use case states the actions taken to delete an existing user role.
Primary Actors	Super-User
Pre-conditions	1. Super-User must be authenticated.
	2. User roles must be configured through UC0.1.1.
Post-conditions	An existing user role is updated with new access rights set by the Super-User.
Basic Flow	1. The System retrieves all the existing User roles with their access rights and displays them.
	2. The Super-User selects the user role that will be deleted.
	3. The System prompts the user to confirm the selection.
	4. The Super-User confirms the selection.
	5. The System deletes the selected user role.
Alternative Flow(s)	If an error occurs, a message is displayed to the Super-User explaining what went wrong
	At step 3, if there exist Users assigned to the selected user role, the System asks the Super-User to re-assign these Users to another user role before deleting it
	At step 4, if the Super-User does not confirm the deletion, then the selected user role is not deleted.

Table 71. Description of UC0.1.4

UC0.1.4	Create User
Brief Description	This use case states the actions taken to create a new user.
Primary Actors	Super-User
Pre-conditions	Super-User must be authenticated.
Post-conditions	A new User is created with access rights set by the Super-User.
Basic Flow	1. The Super-User edits the new User information (username, email, full-name, position in organization).
	2. The Super-User assigns the user role to the user.
	3. The new User is stored in the System.
	4. The new User can access the System with the provided access rights.

Alternative Flow(s)	If an error occurs, a message is displayed to the Super-User explaining what went wrong.

Table 72. Description of UC0.1.5

UC0.1.5	Update User
Brief Description	This use case states the actions taken to update an existing User.
Primary Actors	Super-User
Pre-conditions	1. Super-User must be authenticated. 2. The User to be edited must exist in the System.
Post-conditions	The information of the edited User is updated.
Basic Flow	1. The Super-User edits the User information (username, email, full-name, position in organization). 2. The Super-User assigns the user role to the User. 3. The User updated information is stored in the System.
Alternative Flow(s)	If an error occurs, a message is displayed to the Super-User explaining what went wrong.

Table 73. Description of UC0.1.6

UC0.1.6	Delete User
Brief Description	This use case states the actions taken to delete an existing User.
Primary Actors	Super-User
Pre-conditions	1. Super-User must be authenticated. 2. The User to be deleted must exist in the System.
Post-conditions	The User is permanently deleted.
Basic Flow	1. The Super-User deletes the selected User. 2. The Super-User is prompted to confirm the User deletion. 3. The User is marked as inactive in the System.
Alternative Flow(s)	If an error occurs, a message is displayed to the Super-User explaining what went wrong.

US0.2

Description: *As a super-user I want to configure/update/remove a supply chain from the recommended list by T4M, because I need to be able to fulfil the consumer's registered request for services.*

This user story is based on three use cases:

- (Re-)configure Supply Chain: Describes the actions required to configure or update the supply chain.
- Configure Capability: Describes the actions required to configure or update the capability of a production module.
- Review Supply Chain: Describes the actions required to have an overview of all the available supply chains.

Table 74. Description of UC0.2.1

UC0.2.1	(Re-)Configure Supply Chain
Brief Description	This use case states the actions taken to (re-)configure a supply chain.
Primary Actors	Super-User

UC0.2.1	(Re-)Configure Supply Chain
Pre-conditions	The Super-User must be authenticated.
Post-conditions	The Super-User has configured a supply chain.
Basic Flow	1. The System presents a form with the required configuration fields.
	2. The Super-User edits the required fields.
	3. The Super-User selects to store the selected information.
	4. The System stores this information and generates a DT for this supply chain.
	5. Once the DT (service) is generated, the System stores the information of the service and notifies the user that the supply chain has been successfully stored.
Alternative Flow(s)	If an error occurs, a message is displayed to the Super-User explaining what went wrong.
	At step 1, if the supply chain exists, the System fills the fields with the information of the supply chain.
	At step 4, if the supply chain exists, the System informs the user that it will create an additional DT for the same supply chain. If the user confirms, an additional DT is created.

Table 75. Description of UC0.2.2

UC0.2.2	View Supply Chains
Brief Description	This use case states the actions taken to review the available supply chains.
Primary Actors	Super-User
Pre-conditions	1. The Super-User must be authenticated.
	2. Supply chains must be configured through UC0.2.1.
Post-conditions	The Super-User has a review of all the available supply chains.
Basic Flow	1. The System retrieves all the available supply chains and displays them in a tabular format including basic details of each one.
	2. The Super-User can click on a supply chain that will be used and is directed to UC0.2.1.
Alternative Flow(s)	If an error occurs, a message is displayed to the Super-User explaining what went wrong.

US0.3

Description: *As a super-user I want to configure/update the disrupting events that might occur within the preferred supply chain by the consumer, because I need to have notifications whenever these events occur.*

This user story is based on one use case:

- Compose Disruptive Event: Describes the actions required to configure a disruptive event.

Table 76. Description of UC0.3

UC0.3	Configure Custom Event
Brief Description	This use case states the actions taken to compose a disruptive event.
Primary Actors	User
Pre-conditions	1. The Super-User is authenticated.
	2. Supply chains entities must be configured through US0.1.
Post-conditions	The Super-User has configured a disruptive event.
Basic Flow	1. The System presents a form with the required configuration fields.

UC0.3	Configure Custom Event
	2. The Super-User edits the requested information.
	3. The Super-User submits the edited form.
	4. The System stores the submitted information.
Alternative Flow(s)	If an error occurs, a message is displayed to the user explaining what went wrong.
	If the user configures an existing custom event, they can delete it.

US0.4

Description: *As a user I want to access and manage (activate/update) my account because I need to make appropriate changes to my account details when needed.*

This user story is composed of four use cases:

- Activate Account: Describes the actions required to activate a new User account.
- Login: Describes the actions required to login.
- Edit Account Information: Describes the actions required to edit account information.
- Logout: Describes the actions required to logout.

Table 77. Description of UC0.4.1

UC0.4.1	Activate Account
Brief Description	This use case states the actions taken to activate a new User account.
Primary Actors	User
Pre-conditions	Super-User has created a new User account for this User and the latter has received an email with an account activation link.
Post-conditions	The new User is activated with access rights set by the Super-User.
Basic Flow	1. The User clicks on the activation link.
	2. The User is prompted to login using the auto-generated credentials.
	3. If the authentication is successful, the User is prompted to change the provided password.
	4. The new password is stored on the System and the User is redirected to the home page.
Alternative Flow(s)	If an error occurs, a message is displayed to the user explaining what went wrong.

Table 78. Description of UC0.4.2

UC0.4.2	Login
Brief Description	This use case states the actions taken to login.
Primary Actors	User
Pre-conditions	User has successfully activated the account.
Post-conditions	The User has access to the System.
Basic Flow	1. The User is prompted to provide credentials.
	2. If the authentication is successful, the User is redirected to the home page.
Alternative Flow(s)	If an error occurs, a message is displayed to the user explaining what went wrong.

Table 79. Description of UC0.4.3

UC0.4.3	Edit Account Information
Brief Description	This use case states the actions taken to edit the account information.
Primary Actors	User
Pre-conditions	User is successfully logged in.
Post-conditions	The User account information is updated.
Basic Flow	1. The User edits the password and/or position in the company.
	2. The new information is stored in the System.
Alternative Flow(s)	If an error occurs, a message is displayed to the user explaining what went wrong.

Table 80. Description of UC0.4.4

UC0.4.4	Logout
Brief Description	This use case states the actions taken to logout.
Primary Actors	User
Pre-conditions	The User is successfully logged in.
Post-conditions	The User is logged out and does not have access to the System.
Basic Flow	1. The User confirms the logout action.
	2. The User is redirected to the login screen.
Alternative Flow(s)	If an error occurs, a message is displayed to the user explaining what went wrong.

7 Literature Validation of Requirements and KPIs

In this section, we present an examination of the literature that are relevant to the Tec4MaaSEs (T4M) project as well as an initial mapping of the value networks (VNs) KPIs. Our aim is to uncover the degree to which the requirements and KPIs specified in T4M across its three VNs align with modern manufacturing needs, thereby emphasizing the wide applicability of the T4M approach.

7.1 Literature Validation of Requirements

Sections 3-5 outline the requirements stemming from the three VNs of T4M, which involve various manufacturers with diverse and complementary needs. To address these requirements, T4M will utilize the fundamental concept of a Manufacturing-as-a-Service (MaaS). Implementing this concept allows T4M to meet modern demands for manufacturing as a service and distributed intelligence, providing capabilities such as sustainability analytics, simulation, optimization and self-awareness.

It must be noted that the concept of MaaS can take several forms. In this regard it can be characterized as the servitization of manufacturing (Vandermerwe and Rada, 1988; Hawken, 1993), because the services that are a manufacturer's primary source of revenue differ from traditional services that rely on labour or expertise because customers want to get a service for a product and not product ownership. Additionally, it can be a Product-Service system where there are three phases: product-oriented, use-oriented, and outcome-oriented services. Product-oriented services refer to essential services, such as equipment maintenance; user-oriented services are those in which the provider maintains ownership, such as leasing; and outcome-oriented services emphasize that manufacturers and customers' focus on functional outcomes instead of products (Tukker, 2004). Moreover, the Productive Services (Machlup, 1962; Greenfield, 1966;

Juleff-Tranter, 1996; Yu, 2017), constitute an implementation where the service industry uses human and intellectual capital as the main production factors and provides intermediate services to the production activities of other enterprises and organizations to meet intermediate demand, enabling them to achieve further production operations. Also, Service-oriented manufacturing is defined as the convergence of services and products to improve the profitability of manufacturers by defining the means of how value is added. It has both the characteristics of the physical attributes of manufacturing and flexible performance of services. Crucially, it promotes sustainable development through innovative production and service output processes (Liu et. Al, 2023).

The central principle of Cloud Manufacturing is to offer all types of manufacturing resources as services, efficiently and automatically connecting customers with resource providers who can meet their manufacturing needs. This approach allows for easy scaling of production without significant costs, as companies can "hire more capacities" in the cloud instead of purchasing new machinery, additional trucks, or large warehouses (Liu et. al, 2018; Chiapa et. al, 2023).

Providers registered within a manufacturing-as-a-service (MaaS) marketplace require near real time decision making to accept or reject orders received on the platform. Empirical simulations demonstrate that deep reinforcement learning (DRL) has considerably better performance compared to the four baselines, as proposed by Pahwa and Starly (2021). These are: Tabular Q-learning (TQ), optimization using a rolling horizon approach (RHA), a greedy heuristic (GH) and a random algorithm which selects valid orders randomly in each period. Artificial intelligence and machine learning techniques are generally considered for control data processing, including big data processing and data analytics, and for planning purposes to improve/predict solutions when events or conditions change. There are also applications that use machine learning and artificial intelligence for small product design selection. Studies have shown that a combination of the above technologies, applications, services and processes can define a manufacturing as a service cloud-based system that brings customers, manufacturers, and other service providers on a common and integrated cloud platform (Babiceanu and Seker, 2020).

However, given the large number, broad range, and complexity of cloud manufacturing resources, along with the uncertainty and diversity of cloud manufacturing users, achieving optimal deployment of these resources is a pressing issue. It is crucial to meet the varied individual needs of users and enhance the efficient sharing of manufacturing resources. Work and research have been carried out in this direction, and specifically studies on cloud manufacturing service optimization, cloud manufacturing service comprehensive evaluation system and resource optimal allocation, and used the relevant software tools to design the system function modules and establish a cloud manufacturing service platform system (Cai et. al., 2019).

T4M focuses on deploying technologies as core enablers of Manufacturing-as-a-Service (MaaS) practices. Additionally, through the work inside every value network, T4M aims to demonstrate how a MaaS Marketplace, leverages T4M technologies and provides comprehensive solutions for different manufacturing systems that need to adapt to continuously evolving production needs and market demands.

Consequently, T4M will contribute in advancing conceptual architecture and base technologies, thus contributing to the existing literature of supporting the modern needs of the cloud manufacturing by developing modern capabilities and allowing complex, reconfigurable production systems to be utilised from other companies through a Marketplace, enhanced with DTs for improved control, production speed, cost savings and demand satisfaction.

7.2 Mapping of the Value Networks Functional KPIs to the Literature

In this section, we explore the KPIs identified through the user requirements elicitation process for the T4M project. Additional research has been conducted to pinpoint relevant findings in the literature, providing a comprehensive understanding of how these KPIs have been applied in similar contexts. The goal is to ensure that the pilot KPIs are well-supported by existing research and align with the strategic objectives of the project.

Table 83 summarizes the findings from the literature review. Each KPI ("Pilot KPIs") identified for the pilot project is mapped to corresponding KPIs found in the literature ("Literature KPI"). The table provides detailed descriptions of each KPI ("Definition"), highlighting their importance and impact on various operational aspects such as efficiency, cost management, and customer satisfaction. Additionally, the "classification" of the KPI's ensures a structured approach to analysing and implementing them. The literature sources supporting these KPIs are also listed ("Literature"), ensuring the credibility and relevance of the findings.

Table 81: Classification of the Functional KPIs and Mapping to the Literature

Classification	Literature KPI	Definition	Literature	Pilot KPIs
Production and Operations	Capacity Utilization	The capacity utilization rate is a measure that tells how much of a firm's potential economic output is produced. The calculation is straightforward and is simply the actual output of units divided by the potential output of units.	(Singh et al., 2022)	VN1-KPI1 - Production Capacity Utilization Rate
Customer Service	Order fulfilment (rate) – Customer Service level	Order fulfilment reliability concerns the reliability of fulfilling an order on or before the due date required	Sawik (2016), Chan et al., 2012, C. Chiang et al., 2014, A. Rafael-Abad et al., 2023	VN1-KPI2 - Order fulfilment rate (OTIF)
Inventory management	Manufacturing components/resources/raw materials Stock/inventory	Raw materials inventory refers to a business's stock of materials that have yet to be used in the manufacturing process to create a finished product	Persona et al., 2007 Gontareva et al., 2014	VNI1-KPI3 - Material Stocks
Inventory Management	inventory cost/management/ optimization	Stock levels optimization is the process of maintaining the right amount of inventory required to meet demand, keep logistics costs low, and avoid common inventory issues such as stockouts, overstocking, and backorders	Pınar et al., 2022 Hemant and Shafighi, 2023	VNI1-KPI4 - Finished product stock keeping
NOT IDENTIFIED in the literature, Additional T4M KPI				VN2-KPI1 - Reduction in investment costs (ownership vs. service)

Classification	Literature KPI	Definition	Literature	Pilot KPIs
Production and Operations	(Production) Lead time	This is the amount of time between when a company has all necessary resources on hand to manufacture a product and when it completes the manufacturing process	Balaji et al., 2022	VN2-KPI2 - Product lead time
Costs	Cost optimization – Manufacturing costs	Manufacturing cost is the sum of costs of all resources consumed in the process of making a product. The manufacturing cost is classified into three categories: direct materials cost, direct labor cost and manufacturing overhead. It is a factor in total delivery cost.	Ribeiro et al., 2001 Musca et al 2016	VN2-KPI3 - Manufacturing costs
Inventory Management	Inventory holding costs	Inventory holding costs are the fees incurred for storing goods or inventory in a warehouse. Stored inventory is a liability that hits profit margins and increases businesses' operating costs. Rent for space, security, depreciation costs and insurance are among inventory holding costs.	Azzi et al., 2014	VN2-KPI4 - Investment costs in stored parts
Production and Operations	resource use – resource efficiency	Capacity: The maximum level of output that a company is able to deliver for specific products or product lines on the manufacturing floor. Efficiency: How effective is a company at meeting demands, reaching capacity levels, organizing and managing employees, and maintaining machines.	Gharfalkar et al., 2018	VN2-KPI5 - Resource capacity use
NOT IDENTIFIED in the literature, Additional T4M KPI				VN3-KPI-1: Duration from receival until documents and information are imported and made available in the relevant systems VN3-KPI-3: Number of automated import/export processes
Processes	Communication – documentation technologies in manufacturing	The time and process of communication, verification and documentation	Kurfess et al., 2020	VN3-KPI-2: The timespan between the submission of information and its issuance to the supplier VN3-KPI-4: Verification effort of comments and changes

7.3 Data Sovereignty and Security

Data sovereignty and security are vital elements for any Manufacturing as a Service ecosystem. They ensure that sensitive operational data, such as manufacturing information, remains under the control of its owners while being protected against unauthorized access and threats. Implementing robust data sovereignty and security measures, as detailed in the Gaia-X Architecture Document and exemplified by initiatives like Catena-X, is essential for creating a trusted and interoperable data infrastructure. This infrastructure, in turn, fosters innovation and economic growth while safeguarding the rights and interests of data owners. In the following we provide some basic notions on Data Sovereignty and Data security in data spaces and MaaS. The literature used for this summary is based on the following reports and papers: European Commission report (2016), Digital Transformation in der Industrie, *Gaia-X Architecture Document*, Haße et al (2020), ISO/IEC 27001:2013, Jacoby et al (2021), Landolfi et al (2019), Mertens et al (2022) and Schöppenthau et al (2023).

7.3.1 Data Sovereignty

In the context of data spaces and specifically MaaS, data sovereignty refers to the principle that data generated, stored, and processed within the manufacturing ecosystem is governed by the laws and regulations of the nation where it originates. Since an MaaS ecosystem enables networking along the value chain, this principle is crucial. It ensures that manufacturing data remains under the control of its owners and adheres to local regulations and standards, allowing each stakeholder to manage access to and use of their data according to a governance scheme with specified rules. Compliance with data sovereignty is therefore essential to protect the manufacturing knowledge and business interests of the participating parties.

The key principles of data sovereignty in MaaS include maintaining control and ownership of manufacturing data by organizations, ensuring that data handling practices comply with local laws and regulations, and ensuring that data is portable and interoperable across different systems and jurisdictions. Additionally, transparency in data handling practices is essential for building trust among stakeholders. For instance, Gaia-X (an initiative aimed at creating a federated and secure data infrastructure for Europe) promotes standards and protocols that facilitate seamless data exchange.

To effectively implement data sovereignty in MaaS, several key strategies can be employed: A federated approach is fundamental, as it ensures that services are provided by multiple interconnected entities rather than a single central authority. This decentralization is crucial in ecosystems like, for instance, Catena-X, where manufacturers need to maintain control over their data while collaborating with various partners. Self-Sovereign Identity (SSI) technologies enable organizations to manage their digital identities independently. This supports data sovereignty by allowing data owners to control access to their data and verify the identities of entities requesting access. Clear and enforceable data usage policies are also essential. These policies should outline how data can be used and under what conditions, ensuring that manufacturers retain control over their data. Finally, regulatory compliance tools and frameworks that automate compliance checks and provide audit trails are crucial. These tools help manufacturers meet legal obligations and protect their data, ensuring adherence to sovereignty requirements.

7.3.2 Data Security

Data security is essential for protecting manufacturing data from unauthorized access, breaches, and other threats. In the MaaS context, implementing robust data security measures is crucial for ensuring the integrity, confidentiality, and availability of data. These measures are key to the smooth operation and trustworthiness

of manufacturing ecosystems. The key principles of data security in MaaS include ensuring confidentiality by restricting data access to authorized individuals and entities, maintaining integrity by preserving the accuracy and consistency of data throughout its lifecycle, ensuring availability by making data and related services accessible when needed, and upholding accountability by making data processing activities traceable and holding entities accountable for their actions.

To effectively implement security in MaaS, several key measures are essential. For example, encryption stands as a critical component, ensuring that data remains secure even if intercepted or accessed without authorization. Equally important is the enforcement of rigorous access control mechanisms, which guarantee that only authorized individuals and entities can access sensitive data. Needless to say that in this respect, secure communication protocols, such as HTTPS, TLS, and VPNs, must be utilized to protect data as it flows through networks. Continuous monitoring and logging of data access and processing activities are vital for promptly detecting and responding to security incidents. In this respect, robust frameworks are needed for incident response and recovery by potential security breaches. Compliance with relevant security certifications and established standards are necessary to keep data security. Finally, enhancing security through collaboration is also essential. Building a community of stakeholders, that is, providers, consumers, and regulators, fosters shared threat intelligence, security best practices, and collaborative security initiatives.

8 Business Models of MaaS

8.1 Literature Review of Business Models Applicable in MaaS

The concept of Manufacturing as a Service (MaaS) integrates various business models to create a flexible and resilient service ecosystem. The St. Gallen Business Model Navigator provides a foundational framework with several models applicable to MaaS, and subsequent research and innovation have introduced new models that address modern market dynamics.

8.1.1 Established Business Models from St. Gallen Business Model Navigator

BM2 Affiliation focuses on the secure and efficient sharing of resources, aligning well with the buyer-supplier relationship seen in MaaS. It allows companies to form alliances and share their manufacturing capabilities, reducing costs and increasing efficiency by leveraging each other's strengths (Usländer et al., 2021).

BM30 Mass Customization involves the efficient customization of products using modular architectures while maintaining mass production capabilities. In the context of MaaS, this model allows providers to offer personalized manufacturing services without sacrificing efficiency. Companies can cater to specific customer needs while still benefiting from economies of scale (Gassmann & Frankenberger, 2014).

BM34 Orchestrator emphasizes the coordination of value creation activities within a value chain. For MaaS, this means that a central entity coordinates the various manufacturing processes and activities, ensuring smooth operation and integration of different services and suppliers. This model enhances efficiency and reduces redundancy by delegating non-core activities to specialized entities (Gassmann & Frankenberger, 2014).

BM54 User Design empowers users to design their own products, allowing providers to offer production services without relying on a fixed catalog. In MaaS, this flexibility is crucial as it enables customers to get exactly what they need, thus increasing satisfaction and customization (Usländer et al., 2021).

BM37 Peer to Peer models facilitate direct interactions between users, bypassing traditional intermediaries. In MaaS, this model enhances value creation through community engagement and shared resources, allowing for more efficient and direct manufacturing processes (Frankenberger et al., 2016).

BM52 Two-sided Market acts as an intermediary between consumers and providers, increasing platform attractiveness as more users join. For MaaS, this means creating a marketplace where both manufacturers and customers can meet, negotiate, and transact, thereby enhancing market efficiency and reducing transaction costs (Gassmann & Frankenberger, 2014).

BM13 E-Commerce supports the online delivery of manufacturing services, enabling customers to search for, compare, and purchase services conveniently. This model is particularly relevant in MaaS as it allows providers to reach a broader market and streamline their sales processes (Schöppenthau et al., 2023).

BM48 Subscription implements a subscription-based approach for manufacturing services, providing consistent and reliable access to capabilities on a recurring basis. For MaaS, it ensures a steady revenue stream and long-term customer relationships, as customers subscribe to regular manufacturing services (Usländer et al., 2021).

BM12 Direct Selling enables providers to sell services directly to customers, allowing for better communication, customization, and understanding of customer needs. In the context of MaaS, direct selling eliminates intermediaries, thus reducing costs and improving service delivery (Gassmann & Frankenberger, 2014).

BM40 Rent Instead of Buy allows customers to rent manufacturing equipment or services, providing access to the latest technology without high upfront costs. For MaaS, it offers flexibility and cost savings to customers who need advanced manufacturing capabilities on a temporary basis (Schöppenthau et al., 2023).

BM45 Self-Service Model enables customers to independently select, configure, and order services through an online platform, streamlining procurement and reducing overhead costs. In MaaS, the self-service model empowers customers, increases efficiency, and broadens the provider's customer base without significant additional resources (Gassmann & Frankenberger, 2014).

BM35 Pay-Per-Use allows customers to pay only for the manufacturing services they use, offering cost efficiency and flexibility. For MaaS, it attracts a wider range of customers who prefer paying based on actual usage rather than committing to long-term contracts, optimizing resource utilization (Usländer et al., 2021).

BM49 Supermarket Model provides a centralized online marketplace for a wide range of manufacturing services and products. In MaaS, it enhances visibility for providers and convenience for customers, leading to efficient decision-making and procurement processes (Schöppenthau et al., 2023).

8.1.2 Recent Updates and Extensions

Recent updates have integrated new technological advancements, particularly in artificial intelligence (AI) and machine learning (ML). These updates enable more flexible adaptation of production capabilities, sharing resources, and assets, thus enhancing the design and setup of resilient industrial value networks. Comparative benchmarking of various AI and ML models for supply chain reconfiguration has also been incorporated to improve service decomposition and reconfigurability (Schöppenthau et al., 2023).

8.1.3 New Business Models Developed Post-St. Gallen

Platform Business Models facilitate interactions between multiple user groups, creating value through network effects. The Platform Navigator identifies 88 patterns for designing and implementing platform business models. These patterns help businesses navigate the platform economy, establishing frameworks for platform ownership, complementary strategies, and user engagement (BMI Lab, 2023).

Equipment as a Service (EaaS) focuses on providing manufacturing equipment as a service rather than selling it as a product. This model allows companies to offer their equipment on a rental basis, reducing upfront costs for customers and providing access to the latest technology without the burden of maintenance (BMI Lab, 2023).

Peer-to-Peer and Open Business Models encourage direct interactions between users and leverage external ideas and resources, promoting innovation through collaboration and openness. P2P models enhance value creation through community engagement and shared resources, while open business models leverage external inputs to foster innovation (Frankenberger et al., 2016).

Dual Business Models enable companies to operate in both established and emerging markets simultaneously. This ambidextrous approach allows businesses to exploit existing capabilities while exploring new opportunities, balancing stability with flexibility and innovation (Frankenberger et al., 2015).

Integrated Business Models incorporate the St. Gallen Management Concept to address the complexity of modern markets. These models integrate various aspects of normative, strategic, and operational management, enabling businesses to master the complexity of dynamic market environments (Doleski, 2015).

8.2 New Models Proposed within T4M

T4MBM1 Shared Underused Manufacturing Capacity

This business model focuses on monetizing underutilized manufacturing capacity by offering it as a service to third-party companies. By sharing underused manufacturing resources, companies can generate additional revenue, recover fixed costs, and maximize the utilization of their manufacturing assets. This approach is particularly beneficial for small and medium-sized enterprises (SMEs) that may not have the capital to invest in new manufacturing equipment. Instead, they can access advanced manufacturing capabilities on an as-needed basis, providing flexibility and cost savings.

T4MBM2 Pay per Manufacturing Service

In this model, customers pay only for the manufacturing services they use rather than investing in their own manufacturing infrastructure and expertise. This pay-per-use approach allows businesses, especially SMEs, to access specialized manufacturing capabilities and advanced technologies without significant upfront investments. The model leverages technology to offer a range of manufacturing services through an on-demand platform, optimizing production efficiency and reducing overhead costs. It provides a scalable solution where costs align with actual usage, enhancing financial predictability for both providers and customers.

This business model differentiates from BM35 of Gasmann et al. (2014) in the sense that the consumers do not have any control upon the usage of the providers' assets. Instead, they register their requests and the usage of assets is controlled by the provider. Thus, the payment is decided upon the offered final product/service.

T4MBM3 Service Orchestrator

The service orchestrator model involves actively coordinating multiple suppliers in ad hoc supply chain configurations to provide on-demand services according to their capabilities and capacities. The orchestrator manages the interactions between different service providers, ensuring that each supplier contributes effectively to the overall production process. This model enhances the flexibility and responsiveness of the supply chain, allowing for quick adjustments to changes in demand or supply conditions. It is particularly useful for complex manufacturing ecosystems where coordination and integration of various services are critical for efficient operations.

This business model differentiates from BM34 of Gasmann et al. (2014) in the sense that essentially the T4M platform itself does not have any production capabilities, and thus outsources all the subtasks that should be

performed for the realization of a requested manufacturing service to the Providers registered within the platform.

8.2.1 Identified Business Models for VN1

Value Network 1 (VN1) is particularly suited to several business models, each addressing specific aspects of the network's operational and strategic goals. The selected models include BM2 Affiliation, BM37 Peer to Peer, BM52 Two-sided Market, BM30 Mass Customization, BM34 Orchestrator, and BM54 User Design.

- **BM2 Affiliation**: This model is ideal for VN1 as it focuses on forming alliances and partnerships to share manufacturing capabilities. By affiliating with other companies, VN1 can reduce costs, increase efficiency, and leverage the strengths of each partner.
- **BM37 Peer to Peer**: The P2P model is highly relevant for VN1, enabling direct interactions between users and eliminating traditional intermediaries. This model enhances value creation through community engagement and shared resources, fostering a collaborative manufacturing environment.
- **BM52 Two-sided Market**: VN1 benefits from a two-sided market model, which acts as an intermediary between manufacturers and customers. This model increases platform attractiveness as more users join, facilitating negotiations and transactions that enhance market efficiency and reduce costs.
- **BM30 Mass Customization**: In VN1, Karel utilizes this model for manufacturing electronic boards. It demonstrates how modular architectures can offer customized products without losing mass production efficiency, allowing VN1 to cater to specific customer needs while maintaining economies of scale.
- **BM34 Orchestrator**: Arçelik serves as an example of this model within VN1. The orchestrator model focuses on coordinating value creation activities within the value chain. It ensures smooth operations and integration of different services and suppliers by delegating non-core activities to specialized entities.
- **BM54 User Design**: This model empowers users to design their own products, providing VN1 with the flexibility to offer production services without relying on a fixed catalogue. It increases customer satisfaction and customization by enabling customers to get exactly what they need.

8.2.2 Identified Business Models for VN2

Value Network 2 (VN2) applies a diverse range of business models to cater to its unique requirements. These models include BM2 Affiliation, BM13 E-Commerce, BM37 Peer to Peer, BM52 Two-sided Market, T4MBM1 Shared Underused Manufacturing Capacity, T4MBM2 Pay per Manufacturing Service, and T4MBM3 Service Orchestrator.

- **BM2 Affiliation**: Similar to VN1, this model helps VN2 form alliances to share manufacturing capabilities, reducing costs and increasing efficiency through collaborative efforts.
- **BM13 E-Commerce**: This model supports the online delivery of manufacturing services, allowing VN2 to reach a broader market and streamline sales processes. Customers can search for, compare, and purchase services conveniently online.
- **BM37 Peer to Peer**: The P2P model facilitates direct interactions between users in VN2, enhancing value creation through community engagement and shared resources, and fostering a more collaborative manufacturing environment.

- **BM52 Two-sided Market**: VN2 benefits from a two-sided market model, creating a marketplace where manufacturers and customers can meet, negotiate, and transact. This model enhances market efficiency and reduces transaction costs.
- **T4MBM1 Shared Underused Manufacturing Capacity**: This innovative model focuses on monetizing underutilized manufacturing capacity by offering it as a service to third-party companies. It helps VN2 generate additional revenue, recover fixed costs, and maximize asset utilization, providing SMEs with access to advanced manufacturing capabilities without significant upfront investments.
- **T4MBM2 Pay per Manufacturing Service**: In this model, customers pay only for the manufacturing services they use, offering cost efficiency and flexibility. It allows businesses, especially SMEs, to access specialized manufacturing capabilities and advanced technologies on an as-needed basis.
- **T4MBM3 Service Orchestrator**: This model involves coordinating multiple suppliers in ad hoc supply chain configurations to provide on-demand services. The orchestrator manages interactions between different service providers, ensuring that each supplier contributes effectively to the overall production process. This enhances the flexibility and responsiveness of VN2's supply chain.

8.2.3 Identified Business Models for VN3

Value Network 3 (VN3) leverages several business models to enhance its service offerings, including BM45 Self-Service Model, BM49 Supermarket Model, BM34 Orchestrator, and BM12 Direct Selling.

- **BM45 Self-Service Model**: This model empowers customers in VN3 to independently select, configure, and order services through an online platform, streamlining procurement and reducing overhead costs. It increases efficiency and broadens the provider's customer base without significant additional resources.
- **BM49 Supermarket Model**: The supermarket model provides a centralized online marketplace for a wide range of manufacturing services and products. VN3 benefits from enhanced visibility and convenience for customers, leading to efficient decision-making and procurement processes.
- **BM34 Orchestrator**: Companies like Aibel in VN3 use this model to manage technical agreements and design processes comprehensively. The orchestrator model ensures smooth operations and integration of different services and suppliers by delegating non-core activities to specialized entities.
- **BM12 Direct Selling**: This model enables VN3 providers to sell services directly to customers, allowing for better communication, customization, and understanding of customer needs. Direct selling eliminates intermediaries, reducing costs and improving service delivery.

In summary, each value network applies specific business models that best suit their operational and strategic needs, enhancing their ability to deliver customized, efficient, and flexible manufacturing services. By leveraging these models, VN1, VN2, and VN3 can optimize resource utilization, foster innovation, and maintain competitive advantage in a dynamic market environment.

8.3 Concluding remarks on Business Models

The business models identified for MaaS, categorized into VN1, VN2, and VN3, highlight the importance of flexibility, resource sharing, and efficient customization. By leveraging these models, MaaS providers can enhance their value propositions and better meet consumer demands, ultimately leading to a more resilient and adaptable service ecosystem (Frankenberger et al., 2016; Doleski, 2015). This document provides a

comprehensive overview of the business models applicable to MaaS, integrating both established and newly developed models to address modern market dynamics.

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Annex Section. A brief Description.

This section includes Annexes A through D, all of which pertain to Value Network 2. Specifically, Annex A addresses the manufacturing systems involved, Annex B outlines the selection criteria for the matching process, Annex C provides technical information on resources and the exchange of information between stakeholders, and Annex D contains details on available legacy systems. No similar data is provided for Value Network #1, as its operations involve only a single product type and the outlined Annexes are not available or applicable at this time point. Regarding Value Network #3, the focus is entirely on strategic-level operations, and specifically T4M aims to introduce a new communication and negotiation framework between stakeholders. As such, the specific annexes do not apply in this case. Finally, Annex E includes the elicitation process questionnaire discussed in section 1.2.

Annex A: VN2 Involved manufacturing services

In the framework of T4M a set of manufacturing services, covering specific manufacturing process, will be involved in VN2.

Table 82: VN2 Additive Manufacturing Services (AMS)

Manufacturing service	Additive manufacturing
Description	Additive Manufacturing is a manufacturing process that creates objects layer by layer to form the desired object from digital 3D models. Unlike traditional subtractive manufacturing methods, which involve removing material from a solid block to create a part, additive manufacturing builds up layers of material to form the desired object. This layer-by-layer approach offers several advantages, including the ability to produce complex geometries, reduce material waste, and customize parts with ease. The machine is controlled by a Computer Numerical Control (CNC) system that can execute the instruction contained in a CAM program.
	The additive manufacturing process considered in the framework of T4M is Laser Metal Deposition (LMD). This is an additive manufacturing process in which a feedstock material is melted with a laser and then deposited onto a substrate.

Table 83: VN2 Machining Manufacturing Services (MS)

Manufacturing service	Machining
Description	Machining is manufacturing process that involves the removal of material from a workpiece to achieve the desired shape, size, and surface finish. It is a subtractive manufacturing method, meaning that material is removed from the workpiece to create the final product. The machine could be controlled by an operator (i.e., manual) or by a Computer Numerical Control (i. e., CNC) system that can execute the instruction contained in a CAM program. The following machining processes are considered in the framework of T4M: • *Milling operation*: machining operation which consists of removing material by means of a rotary tool called a "milling cutter" of which there are several different types. Note 1 to entry: The typical milling operations mostly involve face milling or end milling. The tools are mounted either in the spindle taper or on the spindle front face. (ISO 8636-1:2000) • *Drilling operation:* operation which consist of drilling blind or through holes (ISO 8636-1:2000)

	• *Threading operation*: Threads of given pitches are machined on external or internal cylindrical surfaces by means of special thread form cutting tools. (ISO 3655) • *Turning operation*: Turning consists of machining of internal or external, cylindrical or conical or other revolving surfaces by means of one or more single point cutting tools (ISO 3655). • *EDM (Electrical Discharge Machining) process: removal of material in dielectric fluid by electrical discharges, which are separated in time and randomly distributed in space, between two electrically conductive electrodes, and where the energy in the discharge is controlled. Note 1 to entry: The two electrically conductive electrodes are the tool electrode and the workpiece electrode (ISO 28881:2022).* • *Grinding operation:* operation that uses a rotating abrasive wheel as the cutting tool to remove material from the surface of a workpiece.

Table 84: VN2 Plastic Injection Manufacturing Services (PIMS)

Manufacturing service	Plastic injection moulding
Description	Plastic injection moulding is a manufacturing process that produces high-volume plastic parts and components. It utilizes a hydraulic or electric machine, which melts, injects, and sets plastic into the metal mould fitted into the machine. The machine is controlled by a Computer Numerical Control (CNC) system that can execute the instruction contained in a CAM program.

Annex B: VN2 Selection criteria

More than one selection criteria, ranked by priority, may be applicable.

Table 85: VN2 Selection criteria

Criteria	Description
Minimum lead time (days)	Minimum target time between the initiation and completion of the manufacturing service. a production processes.
Target delivery date (date)	Comply with a target delivery date.
Price (euros)	Minimum price for the target manufacturing service.
Distance (km)	Minimum. Distance to the MaaS Consumer To prioritize local providers
Number of providers	Minimum number of different providers. single/multiple providers
Provider quality of service rate (value)	A relevant criterion may be also to know how a potential provider has performed in the past. Potential criteria for such evaluation can be the compliance with the delivery date and the product specifications.
Pre-defined set of providers	Only a predefined set of providers should be considered by T4M
CO2 footprint	This may be also a relevant selection criterion if it can be calculated in the scope of T4M.

Annex C: VN2 Exchanged information template

C.1 Manufacturing resources technical specification

C.1.1 Additive manufacturing resources

Table 86: VN2 Template – Tech. Spec. Additive manufacturing resources

Reference		Reference name
Internal ID		Unique Internal identifier used in the organisation to refer to the specific resource.
Manufacturer		Manufacturer name
Machine type		It refers to the type of machine, Potential values in the framework of T4M are Powder DDE Machine and Wire DDE Machine
Operation mode		It refers to the way the machine can be controlled. Potential values are: • *Manual:* mode of operation where each movement of the machine is individually initiated and controlled by the operator (ISO 13041-1:2020). • *CNC (Computerized numerical control);* automatic control of a process performed by a device that makes use of numerical data introduced while the operation is in progress (ISO 13041-1:2020)
Operation		It refers to the additive manufacturing process supported by the machine. Potential values in the framework of T4M is Laser Metal Deposition.
Supported Axes (Number)		Number of axes. It refers to the degrees of freedom or directions in which the machine can move its tool or workpiece.
Travel distance(mm)	**X length**	It refers to the maximum distance that the machine's tool or nozzle can move along each axis of motion (X,Y,Z). This parameter is important for determining the size and scale of the parts that can be produced using the machine.
	Y length	
	Z length	
Deposition rate [kg/min]		It refers to the speed at which material is added or deposited onto the substrate during the additive manufacturing process. It is a measure of how quickly the material is being built up layer by layer.
Feedstock type		It refers to the form in which the raw material is supplied to the system for deposition onto the substrate during the additive manufacturing process. Potential values in T4M (LMD) are: powder and wire.
Material stock [kg]		It refers to the amount of raw material available for deposition in the form of a powder or wire feedstock. It represents the quantity of material that can be deposited onto the substrate during the additive manufacturing process.
Materials		It refers to the raw material or stock from which a can be manufactured.
Inert environment		It refers to whether or not the machine operates in an inert environment. Potential values are: Yes/No
Explosive materials		It refers to whether or not the machine can machine explosive material. Potential values are: Yes/No Explosive materials for Additive Manufacturing are: magnesium and aluminium
Comments		Any other relevant additional information

C.1.2 CNC machining resources

C.1.2.1 Milling machines, CNC machining centres and Grinding machines

Table 87: VN2 Tech. Spec. machining resources: Milling, turning, grinding.

Reference	Reference name
Internal ID	Unique Internal identifier used in the organisation to refer to the specific resource.
Manufacturer	Manufacturer name
Machine Type	It refers to the type of machine, Potential values in the framework of T4M are. 1. *Milling machine,* machine tool using geometrically defined rotary cutters to remove material in order to produce plane or formed surfaces on a workpiece while advancing (i.e. feeding) the tool or the workpiece in a certain direction (axis movement) or certain directions (axes movements) (ISO 16090-1:2022). 2. *Machining Centre, advanced computer-controlled machine tool that can be used for performing a variety of machining operations and processes. Unlike traditional machines that feature turrets or other mechanisms of manual tool change, an MC consists of an automatic tool-changing mechanism (ATC), allowing for multiple cutting tools to be utilized during the machining process. The core of an MC lies in its versatility, accuracy, and ability to handle complex operations like milling, turning, boring, drilling, and more.* 3. *Grinding machine:* machine tool intended to machine workpieces *by means of rotating grinding tools Note 1 to entry:* The machine can combine different types of grinding methods, e.g. external cylindrical grinding and internal cylindrical grinding (ISO 16089:2015) 4. *Turning machine:* (1) machine tool in which the principal movement is on the rotation of the workpiece against the stationary cutting tool(s). (ISO 13041-1:2020,) (2) machine tool for cutting operations where the main movement is the rotation of the workpiece against the cutting tool(s) (ISO/DIS 23125). 5. Turning centre: (1) NC turning machine equipped with power-driven tool(s) and the capacity to orientate the work-holding spindle around its axis. Note 1 to entry: It can include additional features such as automatic tool changing from a turret and/or magazine. (ISO 13041-1:2020); *(2) numerically controlled turning machine equipped with power-driven tools and the capability to orientate the work holding spindle around its axis Note 1 to entry: A turning centre can also include, but is not limited to, functions such as gauging, burnishing, threading, boring, milling, grinding and drilling. Note 2 to entry: If grinding processes are involved, see* ISO 16089:2015 *for additional safety measures.* (ISO/DIS 23125).
Operation mode	It refers to the way the machine can be controlled. Potential values are: 1. *Manual:* mode of operation where each movement of the machine is individually initiated and controlled by the operator (ISO 13041-1:2020). 2. *CNC (Computerized numerical control);* automatic control of a process performed by a device that makes use of numerical data introduced while the operation is in progress (ISO 13041-1:2020)
Operation	List of supported machining operations. Potential values in the framework of T4M are: 6. *Milling operation*: machining operation which consists of removing material by means of a rotary tool called a "milling cutter" of which there

		are several different types. Note 1 to entry: The typical milling operations mostly involve face milling or end milling. The tools are mounted either in the spindle taper or on the spindle front face. (ISO 8636-1:2000) 7. *Drilling operation:* operation which consist of drilling and blind or through holes (ISO 8636-1:2000) 8. *Threading operation*: Threads of given pitches are machined on external or internal cylindrical surfaces by means of special thread form cutting tools. (ISO 3655) 9. *Grinding operation:* operation that uses an rotating abrasive wheel as the cutting tool to remove material from the surface of a workpiece. 10. *Turning operation*: Turning consists of machining of internal or external, cylindrical or conical or other revolving surfaces by means of one or more single point cutting tools. (ISO 3655)
Axes (Number)		Number of axes. It refers to the degrees of freedom or independent directions along which the machine can move its tool or workpiece.
Travel distance (mm)	**X length**	It refers to the maximum distance that the machine's tool or nozzle can move along each axis of motion (X,Y,Z). This parameter is important for determining the size and scale of the parts that can be produced using the machine.
	Y length	
	Z length	
Max available tool length[mm]		It refers to the available tool length of the available tools,
Min available tool diameter [mm]		It refers to the available tool diameter of the available tools,
Maximum speed (rpm)		Maximum speed refers to the maximum rotational speed of the machine's spindle or cutting tool.
Accuracy (mm)		Accuracy is a measure of how closely the machine can achieve the desired dimensions and tolerances in its machining operations.
Workpiece weight [kg]		Workpiece weight is the maximum weight of the material or part that the machine can handle during machining operations.
Workpiece material		Workpiece material refers to the raw material or stock from which a part is manufactured.
Material Compatibility		Material compatibility indicates the types of materials that the machine is capable of machining, including metals, plastics, ceramics, composites, and others.
Explosive materials		It refers to whether the machine can machine explosive material. Potential values are: Yes/No

C.1.2.2 EDM Machines

Table 88: VN2 Tech. Spec. machining resources: EDM machines

Reference	Reference name
Internal ID	Unique Internal identifier used in the organisation to refer to the specific resource.
Manufacturer	Manufacturer name
Type	It refers to the type of machine, Potential value in the framework of T4M is EDM Machine *EDM equipment*: machine tool that includes all the necessary units for the process of EDM process (ISO 28881:2022)
Operation mode	It refers to the possible mode for use of the machine (ISO 28881:2022)

		Potential values are: It refers to the way the machine can be controlled. Potential values are: 3. *Manual:* mode of operation where each movement of the machine is individually initiated and controlled by the operator (ISO 13041-1:2020). 4. *CNC (Computerized numerical control);* automatic control of a process performed by a device that makes use of numerical data introduced while the operation is in progress (ISO 13041-1:2020)
Operation		*EDM (Electrical Discharge Machining) process:* removal of material in dielectric fluid by electrical discharges, which are separated in time and randomly distributed in space, between two electrically conductive electrodes, and where the energy in the discharge is controlled. Note 1 to entry: The two electrically conductive electrodes are the tool electrode and the workpiece electrode (ISO 28881:2022).
Thickness (mm)	**X length**	It refers to the maximum depth or thickness of material that can be removed from the workpiece during the machining process. It depends on the direction of machining relative to the axes of the machine. This parameter is essential for determining the machining capabilities and limitations of the EDM machine.
	Y length	
	Z length	
Capacity of Work Tank (mm)	**X length**	It refers to the internal dimensions of the machine's tank or reservoir that holds the dielectric fluid during the machining process. This specification defines the maximum size of workpieces that can be accommodated within the tank for EDM operations.
	Y length	
	Z length	
Tolerance (mm)		It refers to the acceptable variation that a machined feature can have from its nominal or target dimension without compromising the functionality or fit of the final part.
Workpiece material		It refers to the raw material or stock from which a part can be manufactured.

C.1.3 Plastic injection moulding resources

Table 89: VN2 Tech. Spec. Plastic Injection Moulding resources

Reference	Reference name
Internal ID	Unique Internal identifier used in the organisation to refer to the specific resource.
Group size	Manufacturer name
Manufacturer	It refers to the type of machine, Potential value in the framework of T4M is EDM Machine *EDM equipment*: machine tool that includes all the necessary units for the process of EDM process (ISO 28881:2022)
Type	Plastic Injection machine
Operation mode	It refers to the possible mode for use of the machine (ISO 28881:2022) Potential values are: It refers to the way the machine can be controlled. Potential values are: 5. *Manual:* mode of operation where each movement of the machine is individually initiated and controlled by the operator (ISO 13041-1:2020). *CNC (Computerized numerical control);* automatic control of a process performed by a device that makes use of numerical data introduced while the operation is in progress (ISO 13041-1:2020)

Operation		Plastic injection
Machine distances (mm) between plates/columns	**X Length**	
	Y length	
	Z length	
Max opening distance		
Screw diameter (mms)		
Material compatibility		6.

C.2 Manufacturing service request information

Table 90: VN2 MS Request

Concept	Description
Manufacturing Services	Involved manufacturing service: AMS, AMS + MachS, MachS or PIMS
Product and process Requirements	AMS, and MachS: Key product and process requirements are embedded in CAD file/2D Drawings. PIMS: Key product and process requirements are embedded in CAD file and Process Parameter Sheet
Number of parts	Number of parts to be produced.
Material	Material of the part to be manufactured is made of
Selection criteria	Selection criteria may vary depending on the situation. In addition, more than one selection criteria, ranked by priority, may be applicable. Refer to ANNEX B.

C.3 Supply chain configuration

Table 91: VN2 Information included in the Supply chain configuration

Concept	Description
Configuration information	Ordered list of providers able to perform the requested service. Including general information of the provider.
Matchmaking information	Relevant information generated by T4M during the matchmaking process: suitable manufacturing resources, part weight and volume, calculated values of the selection criteria, CO2.
Selection criteria	Calculated value of the selection criteria identified by the MaaS Consumer.

C.4 Manufacturing Service quotation request information

Table 92: VN2 Information included in the Manufacturing Service quotation request (MS Quotation Request)

Concept	Description
General information: MS Request information	Summary of the information included in the MS Request as described previously (e.g. manufacturing service, CAD file/2D Drawing, number of parts, selection criteria)

Concept	Description
Matchmaking information	Relevant information generated by T4M during the matchmaking process: suitable manufacturing resources, part weight and volume, calculated values of the selection criteria, CO2.
Additional information	Any other relevant information to support the quotation process

C.5 Manufacturing Service Offer Information

Table 93: VN2 Information included in the Manufacturing Service Offer (MS Offer)

Concept	Description
Offer general information	Summary of the main information included in the MS Request used to generate the offer (e.g. manufacturing service, CAD file/2D Drawing, number of parts, selection criteria) The MS Offer is linked to the MS Request that has triggered it.
Offer Status	Potential status values of the MS Offer are: 1. Released: MS Offer released by MaaS Provider. 2. Rejected: MS Offer reviewed and rejected by the consumer. 3. Accepted: Firm MS Offer accepted by the MaaS Consumer; It includes the final binding conditions.
Information per offer line (linked to specific manufacturing service)	
Provider general information	General information of the provider, including rating.
Price (€)	The price refers to the specified amount of money that the customer is required to pay in exchange for the parts or services being offered. A breakdown of the price of the various services included in the offer should be included (e.g. AM, MS, shipment), as well as the taxes.
Delivery date (Date)	The delivery date refers to the specified date by which the parts or services will be delivered to the recipient or customer. It can vary during the lifecycle of the MS Order (from tentative to agreed)
Validity period	Period during which the offer remains open. The validity date sets a specific timeframe during which the offer is considered valid. It indicates to the recipient how long they have to accept the offer before it expires.
Special conditions	Special conditions or restrictions may be added to the offer to address specific contingencies or risks associated with the transaction.
Comments	

C.6 Manufacturing Service Order Information

Table 94: VN2 Information included in the Manufacturing Service Order (MS Order)

Concept	Description
General order information	The MS Order is linked to the MS Offer and MS Request that have triggered it.

Concept	Description
Order Status	Potential status values of the MS Order are: 4. *Released*: MS Order released by T4M when MaaS Consumer accepts the MS Offer. 5. *Closed*: When the consumer reports that the parts have been received and accepted. 6. *incidence*: When an incidence is detected.
Information per order line (linked to specific manufacturing service)	
General order line information	All the information described in the previous table (for each line/service).
Order line status	Potential status values of the MS Order line are: 7. *Planned*: internal work order linked to the MS Order included in production planning. Updated automatically by T4M. 8. *Produced*: internal work order linked to the MS Order finalised. Updated automatically by T4M. 9. *Shipped*: When the provider reports that it has been shipped (to the next provider or the final consumer) and the shipment number. 10. *Delivered*: When the recipient (next provider in the supply chain or contactor) reports that it has been delivered.
Shipment reference number	When a MS Order is shipped the shipment reference number must be included as part of the MS Order information. To be reported by the MaaS Provider.
Incidence information	Relevant info related to the incidence (if it occurs).
Comments	The order is generated automatically by T4M based on the information in the MS Offer. The MS Order is linked the MS Offer (which in turn is linked to the MS Request).

Annex D: VN2 Legacy systems and data availability

This section identifies the relevant ICT legacy Systems and data sources available in the involved organisations and identifies the **current availability** (AS-IS) of relevant information for T4M.

D.1 Moldes URA

D.1.1 Available legacy systems and data sources

Key data sources available in URA are CAD/CAM systems for product and process information, along with internal databases and datasheets for production planning, or resources use history

Table 95: VN2 URA – CAD-CAM System – CIMATRON

Name	CIMATRON CAD/CAM software
Description	CIMATRON is a CAD/CAM software solution developed by 3D Systems. It is primarily used in the manufacturing industry for designing moulds, dies, and tooling, as well as for programming CNC (Computer Numerical Control) machines for milling, turning, and EDM (Electrical Discharge Machining) operations.
Comments	Vertical solution for the moulding sectors.

Table 96: VN2 URA – CAD-CAM System– NX SIEMENS

Name	SIEMENS NXCAD/CAM software
Description	Siemens NX, formerly known as Unigraphics or UGS NX, is a powerful integrated CAD/CAM/CAE software widely used in various industries, including automotive, aerospace, machinery, and consumer products, for product design, engineering analysis, and manufacturing. It includes specific modules for CAD (Computer-Aided Design) and CAM (Computer-Aided Manufacturing):
Comments	

Table 97: VN2 URA – Manufacturing execution Database

Name	Manufacturing execution Database
Description	Internal Access Database collecting manufacturing execution information.
Comments	

Table 98: VN2 URA – Datasheets

Name	Internal Datasheets
Description	Homemade internal excel datasheets (column /row format) collecting specific information.
Comments	There are different datasheets covering different aspects.

D.1.2 Available data

D.1.2.1 Product and process data

Product and process information is provided by CAD files and 2D drawing.

Table 99: VN2 URA – Product & Process Data – CIMATRON

Data	*Product and process data*	
Data description	Refer to ANNEX A for details.	
Data source	CIMATRON CAD/CAM software	
	CAD File (3D Model)	*.pfm (proprietary) (Neutral file): STEP, IGES, STL, Parasolid x_t, etc. Translators are available.
	2D Drawing	PDF
Comments	Vertical solution for the moulding sectors.	

Table 100: VN2 URA – Product & Process Data – SIEMENS NX

Data	*Product and process data*	
Data description	Refer to ANNEX A for details.	
Data source	SIEMENS NXCAD/CAM software	
	CAD File (3D Model)	(neutral formats). STEP, IGES, STL, Parasolid x_t f,
	2D Drawing	PDF
Comments		

D.1.2.2 Manufacturing resources data

Find below information on the data availability for each manufacturing resource.

- *Production planning data:* Information on resources production planning is collected in homemade data sheets.

Table 101: VN2 URA – Manufacturing resource production planning data

Data	Resource production planning data
Data description	The available information is: *resource ID, order ID, product ID, start datetime, etc.*
Data source	Production planning data sheet
Data source description	Specific internal excel datasheet for manufacturing resources planning.
Data format	EXCEL (row/column) format
Comments	Weekly production planning updated on daily basis, if needed. Homemade excel sheets for internal management. Provide information on resource availability.

- *Manufacturing execution information: Use history*: Historical information on the use of the manufacturing resources is collected including both working time and failure time.

Table 102: VN2 URA – Manufacturing resource use history data- working time

Data	Resource use history data: working time
Data description	Working Time: Data available on *resource ID, date, operation duration, product ID, operator*

Data source	Access Database
Data format	Information can be exported to EXCEL (row/column) format.
Comments	The database includes up to twenty years of information. The information available for a specific manufacturing resource will depend on its acquisition date.

Table 103: VN2 URA – Manufacturing resource use history data- failure time

Data	Resource use history data: failure time
Data description	Failure Time: Data available on *resource ID, month, stop time due to failure, incidence/action.*
Data source	Resource use history datasheets
Data format	EXCEL, format (column/row)
Comments	

D.2 ERREKA

D.2.1 Available legacy systems and data sources

Key data sources available in ERREKA are CAD/CAM system for product and process information along with process datasheets, and Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES) for production planning, manufacturing resources use history and status.

Table 104: VN2 ERREKA – CAD-CAM System – NX SIEMENS

Name	SIEMENS NXCAD/CAM software
Description	Siemens NX, formerly known as Unigraphics or UGS NX, is a powerful integrated CAD/CAM/CAE software widely used in various industries, including automotive, aerospace, machinery, and consumer products, for product design, engineering analysis, and manufacturing. It includes specific modules for CAD (Computer-Aided Design) and CAM (Computer-Aided Manufacturing):
Comments	

Table 105: VN2 ERREKA – Process Adjustment Sheet

Name	Process Adjustment Sheet
Description	Homemade internal EXCEL datasheet for defining plastic injection moulding process parameters.
Comments	

Table 106: VN2 ERREKA – Enterprise Resource Planning

Name	eXPertis Enterprise Resource Planning (ERP)
Description	eXPertis ERP is a software solution developed by Solmicro for enabling efficient data management and improved decision-making across the organization.
Comments	eXPertis can export data in EXCEL format

Table 107: VN2 ERREKA – Manufacturing Execution System

Name	MAPEX Manufacturing execution system (MES)
Description	Mapex MES (Manufacturing Execution System) is a software solution developed by Mapex

	Technologies for optimizing and managing manufacturing operations in various industries. Mapex MES provides real-time monitoring and control of production activities on the shop floor. It collects data from machines, sensors, and operators
Comments	MAPEX can export data in EXCEL format

D.2.2 Available data

D.2.2.1 Product and process data

Product information for the cavity inserts (i.e., spare parts) is provided by CAD files. Process information for plastic injection moulding is available in the Process Adjustment Sheets (in Excel).

Table 108: VN2 ERREKA – Product data – SIEMENS Nx

Data	Product data	
Data description	CAD/2D drawings provide product and process information.	
Data source	SIEMENS NXCAD/CAM software	
Data formats	Product data	
	CAD File (3D Model)	(neutral formats). STEP, IGES, STL, Parasolid x_t f,
	2D Drawing	PDF
Comments	In the case *of injection mould cavity inserts (i.e., spare parts) relevant data must be extracted from the CAD file for resources matching. In the case of* plastic parts manufactured using injection moulding the CAD files are relevant for quality assurance and should be used by the shopfloor operators.	

Table 109: VN2 ERREKA – Plastic injection moulding process data

Data	Plastic injection moulding process data
Data description	Plastic injection moulding process Data.
Data Source	Process Adjustment Sheet
Data format	EXCEL format
Comments	The datasheet does not follow a row and column structure.

D.2.2.2 Manufacturing resources data

- *Production planning*: Information on resources production planning is collected in the ERP and follow up information is available from the MES.

Table 110: VN2 ERREKA – Production planning data

Data	Resources production planning data
Data description	Production Planning: The available information is: resource ID, order ID, start datetime, end datetime, product ID, quantity
Data source	eXPertis Enterprise Resource Planning (ERP)

Data format	Export files: EXCEL/csv (rows and columns)
Comments	

- *Use history*: Historical information on the use of the manufacturing resources is collected in the manufacturing Execution System (MES)

Table 111: VN2 ERREKA – Use history data

Data	Resource use history data
Data description	Resource use history: Resources activity is monitored, and shutdowns are categorised. The available information is: resource ID, start datetime, end datetime, stoppage ID, stoppage type, etc.
Data source	MAPEX Manufacturing execution system (MES)
Data format	Export files: EXCEL/csv (rows and columns)
Comments	

D.3 Tekniker

D.3.1 Available legacy systems and data sources

Key data sources available in Tekniker are CAD/CAM system for product and process information, outlook calendar for production planning, and IoT platform for manufacturing resources use history and status.

Table 112: VN2 Tekniker – CAD-CAM System– NX SIEMENS

Name	SIEMENS NXCAD/CAM software
Description	Siemens NX, formerly known as Unigraphics or UGS NX, is a powerful integrated CAD/CAM/CAE software widely used in various industries, including automotive, aerospace, machinery, and consumer products, for product design, engineering analysis, and manufacturing. It includes specific modules for CAD (Computer-Aided Design) and CAM (Computer-Aided Manufacturing):
Comments	

Table 113: VN2 Tekniker – Outlook calendar

Name	Production planning datasheet
Description	It is used internally to plan the activity of the manufacturing resources.
Comments	

Table 114: VN2 Tekniker – Smart Factory Hub

Name	Smart Factory Hub
Description	Smart Factory Hub is an IIoT platform designed by Tekniker for the capture, storage, and management of information from a variety of industrial equipment, including machine tools, industrial robots, and additive manufacturing equipment.
Comments	

D.3.2 Available data

D.3.2.1 Product and process data

Product and process information is provided by CAD/CAM files.

Table 115: VN2 Tekniker – Product & Process Data – SIEMENS NX

Data	*Product and process data*	
Data description	*Refer to ANNEX A for details*	
Data source	SIEMENS NXCAD/CAM software	
Data format	CAD File (3D Model)	(neutral formats). STEP, IGES, STL, Parasolid x_t f,
	2D Drawing	PDF
Comments		

D.3.2.2 Manufacturing resources data

- *Production planning data*: Information on resources production planning is available from the resource's calendars included in Outlook.

Table 116: VN2 Tekniker – Production planning data

Data	Resources Production planning data
Data description	The available information includes: *resource ID, start datetime.*
Data source	Outlook Calendar/Planning excel sheet
Data format	EXCEL csv (rows and columns)
Comments	

Table 117: VN2 Tekniker – Use history data

Data	Manufacturing execution data: Resource use history data
Data description	Not all the manufacturing resources are currently connected, and the available data depends on the specific machine. Resource use history data: is already being collected for some target resources (Arion-G, Gdy-namic GVC 1000). The available information is: resource ID % of working, shutdown, and standby per day.
Data source	Smart Factory Hub- IIoT platform for manufacturing resources
Data format	Data accessible through API REST (JSON)
Comments	Details of the specified data collected for each manufacturing resource are available in Annex

Annex E: Elicitation Process Questionnaire

Tec4MaaSEs :

Business Requirements and Technical Details Questionnaire

Value Network X

Contents

1 Questionnaire Guidelines

In the following sections you will find indicative questions that will help us establish the Value Network potential interactions as well as set up the premises for your as-is -> to be case.

Initially you will find questions pertinent to the value network and then questions relevant to the organization.

All have pre-filled text derived from the DoA which is to be examined / updated / extended by each participant in the value network

2 Value Network X – To be completed / updated by each participant

2.1 Summary Overview of organizations in relation to the value network

Please provide an overview of the manufacturing organization within the context of Value Network X – Role
AS IS:
TO BE:

2.2 Overview of involved stakeholders in relation to the value network

Please provide the as-is situation of the involved stakeholders (groups / divisions / individual employee roles) that need to be involved for the analysis, design, implementation and adoption of the Tec4MaaSEs offerings (e.g., plant floor employees, technicians, plant floor managers, production managers, production experts, regional managers, business unit managers, senior management, key-partner companies, corporate social responsibility team) and are involved in value network's 1 interactions. Below you can find information from the initial mini-workshop

ID	Participant	Type	Role	Description	In-volve-ment	Im-pact
	Please add rows re-spectively					

2.3 Overview of involved interaction / stakeholder in relation to the value network

*Please provide the **as-is situation** of the high-level process based on which you currently conduct all interactions in sequential form*

3 Tec4MaaSEs Individual Production Requirements

3.1 Overview of organization, products, production processes and stakeholders

Please provide an overview of the organization, its products, the examined industrial premises and corresponding processes.
Overview:

3.2 Description of the as-is situation

Describe the focus of your involvement in Tec4MaaSEs (i.e., the pain areas with respect to specific production processes) and the kind of processes that are related to these pain areas.
Why use MaaS ? Which are the problems faced currently that the MaaS will resolve?

***For the case of your value network*: Describe the nature and specifics of collaboration and collaboration relationships (e.g., SLAs, if relevant to the pilot).**
Inbound Collaboration: ***Elaborate based on input from suppliers***   **Outbound Collaboration:** ***Elaborate based on output towards Large European Energy producers***

Breakdown of the process steps relevant to the processes
•

Describe the KPIs you wish to improve (both operational and environmental) and their priority levels in terms of impact/importance to your organization. Please also provide the current values/ranges if these KPIs are currently being measured.
Local (within scope of Tec4MaaSEs):

3.3 Description of the to-be situation

Describe your goal within Tec4MaaSEs.
Goal 1-X: *build information models which associate information to these designations, both attribute information, classifications, and relation*

For the case of your participation in Value Network 1: Describe the improvements in the collaboration you wish to achieve.
Improvement 1-X:

Set the targets for your collaboratively produced / monitored KPIs (both operational and environmental).
Value Network KPIs into which you will participate and/or believe are critical for the success of Tec4MaaSEs:

Specifics on the to-be improvements (if applicable) regarding Optimization: Please provide: a) short verbal description of the process you wish to optimize (what is to be optimized) and its impact with respect to the pilot; b) set of decisions (what can be the different options to solve the problem); c) set of constraints (what parameters govern sets of feasible options); and
Local: • A) • B) • C) Within Value Network: • A) • B)

- C)

Specifics on the to-be improvements (if applicable) regarding analytics.

Please provide (for each Use Case foreseen):

a) short verbal description of the asset(s) and the issue(s) you wish to prevent/

b) how is the current situation (respect to the issue(s)) handled?

c) What kind of output do you expect from the self-awareness?

d) Description of available KPIs and data with respect to time-horizon (what is the time span of the available data) and time-granularity (e.g., per second, per minute, per day) in relation with self-awareness

e) What are the KPIs that you are not currently assessing, and you would like to

Local:

- A)
- B)
- C)
- D)

Within Value Network:

- A)
- B)
- C)
- D)

Specifics on the to-be improvements (if applicable) regarding creating Information Models of Assets for VN interactions:

Please provide:

a) short verbal description of the type of documents you wish to transform to information models and its impact with respect to the pilot;

b) set and flow of transactions required with your suppliers in order to arrive to an agreement

c) set of data you provide to your suppliers

d) set of data you expect from your suppliers in their answers to your requests

e) set of constraints (e.g. time?, others?) that should be respected in the transactions with your suppliers

Local:

- A)
- B)

- C)

Within Value Network:

- A)
- B)
- C)

3.4 Existing ICT infrastructure and data access/availability

Describe the data that is available as well as the sources of this data (MES, ERP, WMS, production DBs, manufacturing systems, Maintenance Management System, etc.). For each data source, clarify if there is an API to access it.

Local:

- ….. (ERP) :
- ….. (MES) :
- ….. (WMS) :
-

Within Value Network (currently how you conduct the ordering / logistics etc. relevant):

-

Can you provide data on real-time or only historical data are available? Are there any restrictions to the provision of data in real-time?

Local:

Within Value Network (What you can/want to share):

Do you want to keep data related to your industry collected/processed at the edge layer (i.e., in a Computer Room / Datacenter within the factory), or at the Cloud (i.e., hosted in a Cloud provider)?

Local:

Within Value Network (What you can/want to share):

Describe the type of data that is currently NOT available but required for achieving your goals / meeting KPIs in Tec4MaaSEs (if applicable). Describe what sensors/systems need to be installed, where the data will be stored, and how it will be accessed.

Local: **Within Value Network (What you can/want to share):**

Describe the data exchange protocols that are available (if any) in the involved production machines/lines (e.g., OPC UA, HTTP). If proprietary protocols are used, clarify if documentation is available.
Local: **Within Value Network (What you can/want to share):**

Describe how existing data maps on the KPIs you defined.
KPI 1: **KPI 2:** **----** **KPI x:**

Describe the data that needs to be measured with respect to KPIs currently not measured.
Please provide your answer for each of the stated KPIs

Describe the existing decision support solutions (e.g., production scheduling software, simulation systems, digital twins/shadows etc.) that are currently used and present who uses it (stakeholder). If any, clarify whether and how these systems can be integrated or interacted with.

How many (if any) Digital Twins do you foresee that are related to your use case(s) and how do they relate with the value network ?

What service(s) should be provided/supported by a (or more) Digital Twin(s) to be developed in Tec4MaaSEs?