RAASCEMAN

Resilient and Adaptive Supply Chains for Capability-based Manufacturing as a Service Networks

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Deliverable 1.1

Requirements and specifications

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Does this report contain **confidential** information?	Yes ☐ No ☑
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Executive Summary

This deliverable provides a comprehensive report of the method and results of the requirements engineering of the RAASCEMAN software system. First, we describe the requirements engineering methodology we followed. This process involved all RAASCEMAN project partners, with on the one hand system architects, who will be responsible for creating (parts of) the RAASCEMAN system and are represented by DFKI, FLM, RPTU, CTU, INTRA, LMS, CEA, and on the other hand users of the RAASCEMAN system represented by pilot case owners CONTI, ASKA, DFKI, RPTU, CTU, FLM. Next, the results of the different phases of the methodology are reported in the following sections, namely the overall needs from the point of view of the RAASCEMAN system users, a translation to use cases and user stories that describe the functionality of the RAASCEMAN system from a high level, followed by requirements of the system. The result of the methodology is a living document of requirement artefacts (use cases, user stories, requirements) that are available throughout the project, and are meant to be tracked, updated, and extended in the remainder of the project.

1 Introduction

1.1 Objectives

This deliverable is a report describing functional and technical requirements of use cases and external stakeholders on different hierarchies of the supply chain (shopfloor to manufacturing-as-a-service (MaaS) network).

This task will focus on the analysis and extraction of stakeholder (predominantly user) requirements in functional and technical terms. The target is to define requirements that can relate to external stakeholders from the wider European manufacturing industry. The requirements will cover multiple fields from the supply chain level to the shop floor level such as supply chain control, impact prediction of unforeseen events, trust and reliability issues on the supply chain level, production planning and scheduling, etc. FM leads this task and will define the requirements for the bike use case with ASKA. CTU will contribute by defining the requirements within the automotive use-case with CONT. DFKI, CEA, INTRA and LMS will add additional requirements and specifications.

1.2 Methodology

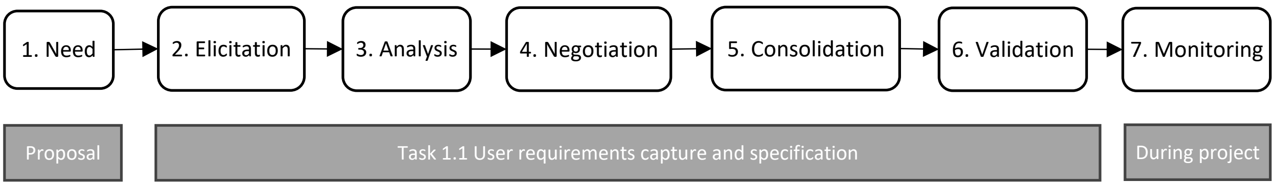


Figure 1: Overall requirements engineering process

Figure 1 shows the overall requirements engineering process we used for RAASCEMAN. We use generally accepted requirements engineering techniques to capture and specify the requirements of the RAASCEMAN system. The RAASCEMAN system is the software system resulting from the project with the main purpose of enabling a decentralized capability-based MaaS network that creates resilience for European supply chains while enabling the human to make informed decisions in case of medium- and short-term disruptions. It consists of a number of tools to support such a MaaS network.

We explain each step of the requirements engineering process below and motivate why the chosen methods are most suitable. The process is carried out by members of the consortium representing **system architects**, who will be responsible for creating (parts of) the RAASCEMAN system and are represented by DFKI, FLM, RPTU, CTU, INTRA, LMS, CEA, and **users** of the RAASCEMAN system represented by pilot case owners CONTI, ASKA, DFKI, RPTU, CTU, FLM.

1.2.1 Need

We start from the high level needs as described in the project proposal, written in the objectives and challenges. They are revisited in Section 2.

1.2.2 Elicitation

The goal of requirements elicitation is to:

- Identify the **stakeholders** of the RAASCEMAN system
- Identify **high level use cases and interaction** with the RAASCEMAN system
- Identify the **scope** of the solution
- Identify **evaluation criteria and acceptance criteria** that allow to measure whether a requirement is met

The method was as follows:

- System architects conducted the **Interviews** for the three pilot cases. These were interviews with the envisioned RAASCEMAN system users: on the one hand the industrial partners refining their need, and on the other hand the MaaS experts who define the interconnected pilot lines. The Maas experts represent broader European manufacturing industry.
- System architects **brainstormed and role played** on general needs beyond the industrial pilot cases.
- We used **BPMN** to elicit **user interaction** with the RAASCEMAN system.
- We developed a **glossary** for several key aspects of the system to improve understanding of the RAASCEMAN system.

The results of the requirements elicitation phase are reported in Section 3. The section represents the needs from the point of view of each individual pilot case.

1.2.3 Analysis

The goal of the requirements analysis phase is to:

- Translate the user needs into **features and intended use** of the system
- Specify clear, complete, consistent **requirements**

The method was as follows:

- System architects provided overall overview of the system by identifying the most important **system-level use cases** and showing them in a system diagram.
- System architects described the key functionality of the system for these use cases, using a **use case template.**
- System architects defined **user stories** to describe all user needs to complement the use cases.
- To further elicit use cases and user stories, system architects defined structured **requirements** where necessary, inkling business, technical, functional and non-functional requirements.

We select a number of key use cases to elaborate and understand the goal and interaction of the user with the system. The use cases were selected based on their contribution to explaining the overall system. System-level use cases describe scenarios that may involve several user stories if it needs to be shown how they work together.

Not all behaviour needs to be or can be elaborated in a specific use case scenario during the requirements analysis phase. Therefore, we complement use cases with user stories to capture the user needs in a concise and user-friendly way. The goal is to come with a complete set of user needs. The user stories are not intended for agile software development, so we do not use these to plan sprints. Therefore, user stories can represent a large amount of research. Use cases and user stories are reported in Section 4.

Based on use cases and user stories, we extract the requirements. We focused on formulating requirements that add new information on top of the use cases and user stories. Requirements are reported in Section 5.

1.2.4 Negotiation

The goal of this phase is to agree on the requirements with all stakeholders, more specifically system architects and users that will validate the RAASCEMAN system in the pilot cases.

The method we used was in several stages: we conducted **evaluation workshops** with system architects and users of the pilot cases to go through use cases and user stories, resulting in alignment between all RAASCEMAN consortium partners, and peer **reviews** of use cases, user stories and requirements.

Part of the negotiation resulted in a **glossary** of Section 3.4, which was essential in creating unambiguous and understandable requirements.

1.2.5 Consolidation

The consolidation phase has as goal to **document** requirements so that they are usable for all stakeholders. The goal was to create documents and models that can be monitored throughout the project. The requirements for these documents were:

- **Updatable**: the requirements are not set in stone after D1.1 deliverable and the project team should be able to update them and adopt a more agile approach towards requirements management.
- **Single point of access**: the current state of the requirement should be available at all times to all stakeholders from a single point.
- **Low technical threshold**: the requirements should be used by people that have limited experience with requirements engineering.
- **Well structured**: we use generally accepted formats like user stories, use cases and requirements that follow well explained templated in order to improve clarity, conciseness, and consistency.

The result of this phase is this **D1.1 document** that timestamps the requirements at M6 of the project after the requirements engineering process, and a set of **collaborative documents** for tracking and updating requirements throughout the project in Excel and bpmn.io format, hosted in the cloud (SharePoint). We preferred this simple, accessible approach of using existing requirements tools.

1.2.6 Validation

The goal of the validation phase is to validate the agreement of all stakeholders on the requirements. The system architects and users reviewed the requirements for consistency and completeness. The deliverable D1.1 was reviewed in its entirety for overall consistency and quality.

1.2.7 Monitoring

The requirement artefacts (use cases, user stories, requirements) are used throughout the execution of the project. We need to allow:

- tracking of completion;

- changing of use cases, user stories and requirements.

For this reason we added columns for tracking, and IDs for referring to requirement artefacts in our collaborative Excel documents to track use cases, user stories and requirements.

2 Overall Needs of the RAASCEMAN MaaS System

This section is a summary of the high level needs of the system that define the high level scope of the RAASCEMAN MaaS system. The RAASCEMAN MaaS system will address the following high-level challenges. This section is copied directly from the RAASCEMAN proposal and is added for context in this deliverable.

2.1 Challenge 1: Common semantic representation

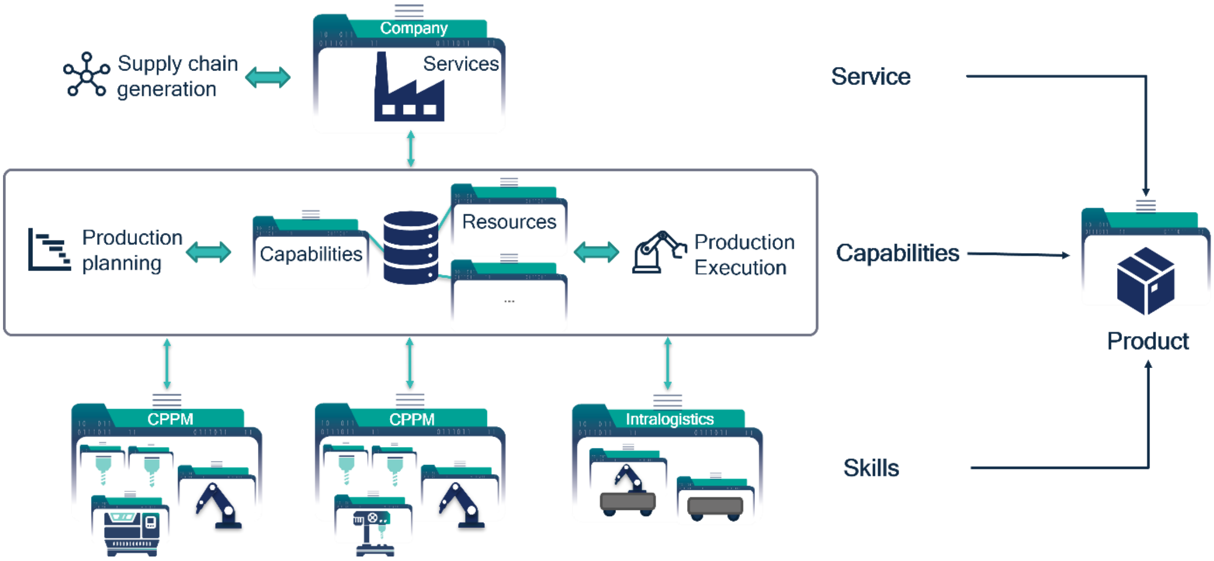


Figure 2: Comprehensive semantic representation for establishing a common understanding

RAASCEMAN tackles the challenge of transferring information about unforeseen events, products, factory services and machine capabilities within a MaaS network. Standardized and integrated software components using a **common semantic representation** are a prerequisite for intra- and cross-company communication and transparency across the MaaS network. In the project semantic representations will be developed for the interoperability of software components, semantics-based information processing and human decision making.

To achieve these objectives the factory and machines will be described according to the **Capability, Skill and Service (CSS)-model**[1], which is developed by the Platform Industrie4.0 using standards such as AAS and OPC-UA. For finding suitable suppliers, generating production plans and executing these production plans all the relevant details about a product must be described with its **Product Digital Twin (PDT)**, which will be based on the AAS and augmented with several type of knowledge about the production Figure 2 gives and overview of the semantic representations developed in RAASCEMAN.

The **CSS-model** (Task 2.1) represents a holistic system architecture enabling connectivity from the MaaS network level down to the machine (shop floor level). The services are a description of the commercial aspects and means of provision of offered capabilities of a factory that are made available

1 https://www.plattform-i40.de/IP/Redaktion/DE/Downloads/Publikation/CapabilitiesSkillsServices.pdf?__blob=publicationFile&v=1

in the MaaS network. That makes it possible to find suitable suppliers in the MaaS network based on the offered services described in the AAS of each factory and the required services described in the AAS of the PDT. The capabilities are the implementation-independent specification of what can be produced by the machines of the factory. It enables companies to efficiently decide whether a product can be manufactured with the available machines. The skill then provides the interface to the field level to realize the production execution on the available resources in a factory.

The **PDT** (Task 2.2) will contain all relevant information to perform step-by-step quotation generation, prepare production plans and execute manufacturing at the field level. Since RAASCEMAN also tackles the case of remanufacturing the PDT will also contain additional information such as usage information to enable companies to evaluate if remanufacturing is possible, and information related to other lifecycle steps of the product including decommissioning.

2.2 Challenge 2: Intra- and cross-factory communication based on standards and European values

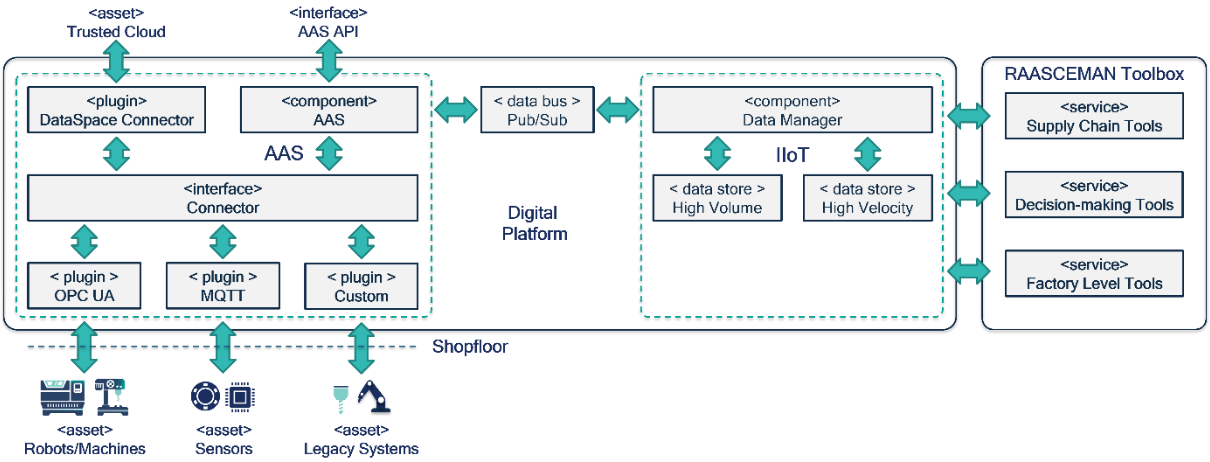


Figure 3: Communication infrastructure to enable intra- and cross-factory communication

RAASCEMAN tackles the challenge of **intra- and cross-factory communication** by enabling trusted data exchange **based on standards and according to European values**. That includes clear specifications of interfaces and a modularized system architecture. To enable connectivity from the machine up to the MaaS Network several different standards and communication protocols must be provided by the digital platform and the middleware. This includes mechanisms for the registration and discovery of manufacturing services as well as vertical integration.

A reference architecture of the cross-company and intra-company infrastructure developed in RAASCEMAN is depicted in Figure 3.

For the **intra-company infrastructure** (Task 2.3), the platform exploits the AAS capabilities and demonstrate the interoperable features of the AAS by providing apart from the AAS themselves (AAS for processes, resources, digital twins, ERP software etc.) a platform where these AAS will be deployed and all software systems can interact with a single source of truth concerning data. The platform itself takes care of the integration and communication layers of the various AAS as well as providing security by regulating information and message exchange. The platform contains three main components concerning the AAS. The AAS repository where the AAS model along its data are residing, the AAS data manager component and finally a central authentication system for security and authorization concerns.

On top of this, the **cross-company** (Task 2.4) communication between organizations in a supply chain network, will be developed by the implementation of specific GAIX-X interfaces (IDS/EDC) to allow information exchange in an open, transparent and secure digital ecosystem assuring digital sovereignty of each individual data owner as well as interoperability between different data platforms. Additionally, the digital platform will deploy different kinds of datastores to enable the implementation of the RAASCEMAN use-cases. Thus, the platform represents the foundation for the tools achieving the impact prediction of short- and medium-term unforeseen events, human decision making as well as adapting production and supply chain.

2.3 Challenge 3: Enabling human decision maker to react to unforeseen events

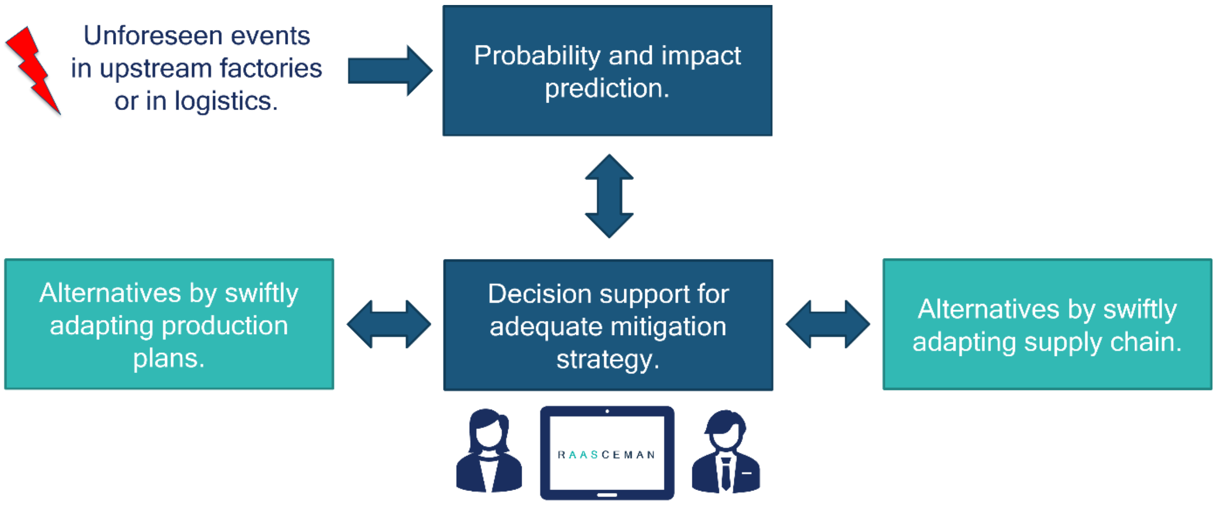


Figure 4: Enabling human decision maker to react in case of short- and medium term unforeseen events

RAASCEMAN tackles the challenge of enabling an informed decision in case of short- and medium-term unforeseen events. Manufacturing strives to be resilient and flexible in order to dynamically adapt to fluctuations that may occur in the whole supply chain such as changes in the market demand, raw materials and logistics. Thus, the main challenge for different manufacturing sectors to overcome is to be able to **predict on time different kind of unforeseen events and evaluate their impact** towards achieving a more dynamic and efficient planning of their resources and processes in the whole manufacturing value chain. These decisions can be very complex and depend on the role of the company in the network. In order to take the best decisions, decision makers need to be able to **draw timely conclusions based on a variety of different data and knowledge sources**.

To enable human decision makers to make informed decisions in case of short- and medium-term unforeseen events first a **prediction of probability and impact** of the unforeseen event is required. Additionally, a **decision support** is needed for developing mitigation strategies comparing possible alternatives to react to the unforeseen event including the associated costs (Figure 4).

Until now a holistic solution for the **prediction and quantification of impact** (Task 3.1) in the supply chain is missing that can cover the whole spectra of core unforeseen events affecting manufacturing networks as well as its efficient integration with the internal planning for companies. The existing work on Bayesian networks will be further extended to incorporate additional short- and medium-term unforeseen events and risks that will be modelled within the project's use-cases. Furthermore, integration with the supply chain tiers and with decision-making tools will be targeted incorporating different kinds of uncertainties. RAASCEMAN will utilize scenarios that start from probability distributions of parameters rather than fixed values, propagating the uncertainty through the analysis. This provides the user with additional information that enhances the quality of decision-making. Production managers can consider the calculated likelihood of possible outcomes in addition to their own experience-based heuristics.

Decision support (Task 3.2) requires not only information on the probability and impact of an unforeseen event but also actionable propositions for alternative strategies adapting his own production or searching for alternative suppliers. This allows human decision maker to compare the costs of alternative strategies with the impact prediction of the unforeseen event and to make an informed decision. With all the information the human decision makers need support drawing the right conclusions from the provided information. In RAASCEMAN knowledge graph-based technologies are applied in the context of a dynamic supply chain and are improved to provide access to the data and knowledge sources that are required by the decision makers in the company network. In addition, semantic reasoners are used to support the decision makers to further accelerate the time necessary to draw conclusions.

2.4 Challenge 4: Enable companies to swiftly find suppliers and ensuring trust and reliability

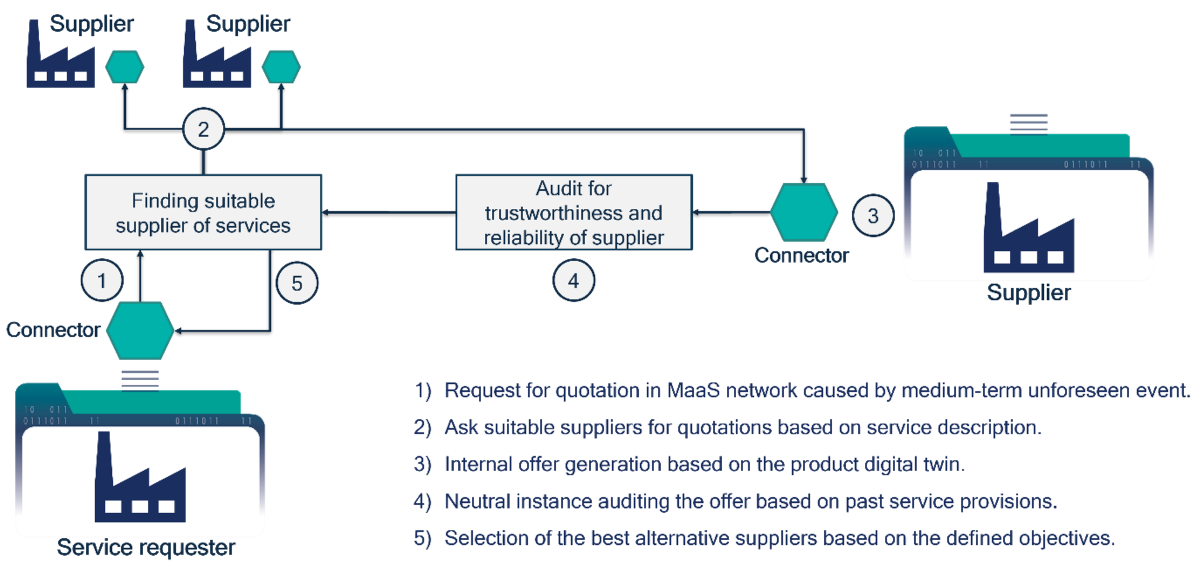


Figure 5: Tools to enable companies to swiftly find suppliers and ensuring trust and reliability

RAASCEMAN tackles the challenge of facilitating the search for suitable suppliers and create trust in a decentralized MaaS network to enable the reaction to medium-term unforeseen events. In order to realise a trusted MaaS network, the **selection and orchestration of suppliers** in the network are of great importance. To select and coordinate the required suppliers, there must be a **possibility to compare** them against each other. However, the suppliers' **service descriptions need to be validated** in a trusted MaaS network. The requesting company has to be sure that the supplier can guarantee the required quality of the product in case of unforeseen events.

To select suitable suppliers in a decentralized MaaS network RAASCEMAN will develop the following approach (Figure 5). To select suitable suppliers (1) the service requester uses a **recommendation engine** which compares the service descriptions of the suppliers in the network with the requirements of the requested product and asks suitable suppliers for a quote (2). Based on the digital product twin the supplier can then generate a quote (3).

To provide a measures for trustworthiness and reliability the **Supply Chain Audit Tool** (Task 3.3) will validate the quote based on past products (4). With all quotes and their rating, the recommendation engine can select the best alternative suppliers optimizing the quotes according to the KPIs defined by the service requester (5).

To ensure trustworthiness and reliability throughout the dynamic supply chain, a **supplier audit tool** is being developed (Task 3.3). By analysing historical data from suppliers, including quotations, production plans and other relevant documents, we gain valuable insights into the types of parts produced, the machines and tools used for this purpose, and the quality of the final results. This data is analysed to identify patterns and trends that allow us to identify the supplier's capabilities based on their past performance. In addition to analysing historical data, critical process procedures, quality control measures, maintenance modalities, inspection procedures and sourcing criteria are considered in a second step. RAASCEMAN develops the supplier audit tool based on a knowledge graph that links the existing supplier data in a meaningful way and computes a similarity measure to evaluate quotes. Each supplier in the chain is mapped with its own KG.

In order to dynamically find the best supplier for the required product requirements at runtime, a **recommendation engine for dynamic identification of suppliers** is developed (Task 3.4). The first step is to define and analyse the relevant product requirements to be produced by the supplier. This includes factors such as materials, specifications, quality standards and production volumes. The second step is to define and analyse the relevant supplier capabilities. This may include factors such as production capacity, experience, equipment, certifications and quality control processes. The information is then transformed into an information model that represents the product requirements and supplier capabilities in a way that enables or facilitates semantic matching. The information model is a general self-description that is tailored to the specific requirements of the supply chain. On this basis, a semantic matching algorithm is developed that compares the product requirements with the supplier's capabilities. The algorithm takes into account factors such as the importance of each requirement, the relevance of each capability and the degree of match between each requirement and capability. Once the semantic matching algorithm is working effectively, it is integrated into a recommendation engine that generates a list of recommended suppliers based on the product requirements and optimizes the selection based on KPIs defined by the service requester. To make the recommendation engine applicable in the remanufacturing scenario the information model must just be extended by additional information about the quality of the product.

2.5 Challenge 5: Enable companies to swiftly create quotes and adapting production

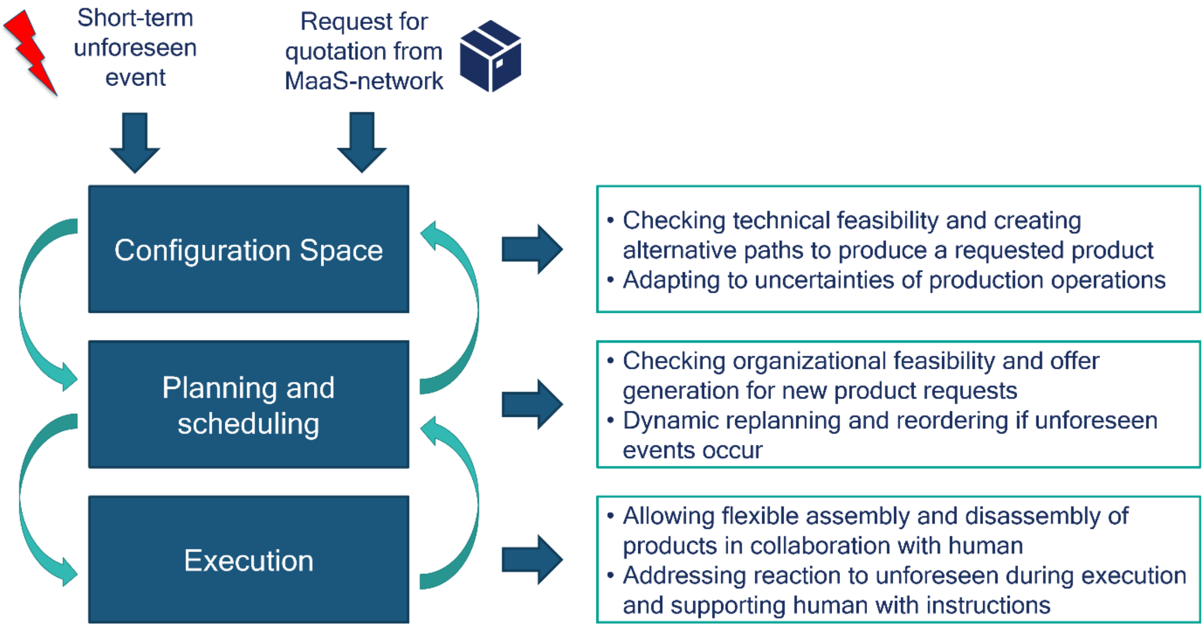


Figure 6: Enable companies to swiftly create quotes and adapting production in case of short- and medium-term unforeseen events

To tackle short- and medium-term unforeseen events RAASCEMAN aims at reducing time and effort for production planning, scheduling and execution enabling a dynamic reaction to unforeseen events inside the factory and enable the companies to participate in a MaaS network. In general, these tasks are hard to solve challenge which becomes even harder if the problem complexity increases. In a MaaS network companies must be able to **analyse the technical feasibility** to produce an unknown product with their available equipment and map product requirements to capabilities of machines with the objective to **identify possible production plans**. When alternative production plans are developed **organizational feasibility** must be validated and the **production of all products must be scheduled estimating KPIs** such as costs, delivery dates and environmental impact resulting in a multi-objective optimization problem. In the scope of this project, the planning receives additional information from the supply chain layer which increases the complexity and has a significant impact on the low-level optimization. To enable companies to participate in a MaaS network not only the planning but also the execution of production must be more flexible. Nowadays, **processes at the field level are often bound to rigid procedures**. If a company manufactures in small batches, many tasks are solved manually. There is the need for dynamic execution of assembly and disassembly in case of remanufacturing allowing both human and machines to cooperate.

Figure 6 shows the connection of the interrelated challenges. To objective is to react to short-term unforeseen events or swiftly create quotations for the MaaS network enabling reaction to medium-term events. First the configuration space (all relevant possibilities to produce a specific product) as foundation of optimizing the production must be determined. This is done by a **capability matching** (Task 4.1). Using the results, a **dynamic planning and scheduling** (Task 4.2) is able to optimize the production, stock level and logistics and create quotes for requested offers. The **dynamic execution** (Task 4.3) finally allows the flexible assembly and disassembly in collaboration with human operators.

The initial step for production planning and scheduling is the **matching of appropriate manufacturing resources and their capabilities to required operations** (Task 4.1). The pool of potential resources is sorted by their capabilities of executing the abovementioned operations. Finally, the matching between operations and resources is performed regarding technical as well as economical aspects. Resources that do not fulfil the necessary requirements in a satisfying manner can be removed from the pool of alternative resources. The selection of resources allows the creation of manufacturing sequences in a following step. A manufacturing sequence in this context can be defined as the conjunction of value-adding, resource-oriented manufacturing steps and non-value-adding processes. While the before mentioned phase dealt with the isolated matching of operations and resources with the goal to create a feasible solution for one manufacturing task, it is the full chain including all intermediate steps. RAASCEMAN will use the combination of a centralized component based on a planning algorithm e.g., PDDL and decentralized component that uses a multi-agent approach for the creation of possible production sequences.

In order to optimize the intra-factory processes in a **dynamic production planning and scheduling** (Task 4.2) the information from data systems inside the factory and the information outside the factory must be taken into account. All of this information is transformed into a model that represents the factory. Using this model, RAASCEMAN can simulate different possibilities and states of the factory in the future. If new events will occur, we can re-simulate a possible solution to adapt it to the new event. The adaption of simulation logic will be one of the new features that needs to be implemented. This enables the possibility to improve the optimization results and the overall production process. The method will be designed as a real-time approach, where real-time means that we should receive a result within at most several minutes (which is usually sufficient in industrial contexts). To reach this goal, we trade of runtime against the quality of the solution. In small environments, we successfully used Deep-Q-Learning methods to simulate and optimize a production line ensuring AI technical, social robustness and reliable and function. This method will be further improved to react on dynamic changes in the environment on the one hand and to handle more complex scenarios on the other hand.

To react to unexpected events in supply chains, it is also necessary to be able to **flexibly execute manufacturing tasks at the field level** (Task 4.3). For this purpose, a flexible interface to the resources is established in order to be able to trigger different tasks dynamically. The interface to the field level will be a standardized skill interface. New programming methodologies and algorithms can enable machines to respond to unexpected events or changes in workflow. RAASCEMAN allows production processes to be dynamically adapted, resulting in a lower probability of production process failure based on MPC. It is equally important to include humans in this concept and to provide them with flexible instructions based on the digital product twin.

3 Requirements Elicitation

This section shows the outcome of the requirements elicitation phase. In this section we discuss for each pilot case what the stakeholders of the RAASCEMAN MaaS system are, what unforeseen events the system needs to present a solution for, and their specific goals for the system.

3.1 Users from the bike pilot

3.1.1 Context and rationale

Prior to the RAASCEMAN project, ASKA bikes operate within the following context:

- **No manufacturing operations:** ASKA does not perform any manufacturing, neither of components, nor assembly. All manufacturing and assembly operations are outsourced. ASKA can indirectly influence manufacturing by design for manufacturing, or by providing exchanging the right information to manufacturers.
- **Few suppliers:** ASKA now has access to single suppliers for many of their crucial manufacturing steps, e.g., frame manufacturing, assembly. They need access to new suppliers and more flexibility in their supply chain. There is a need for quick quotations and procurement.
- **Fluctuating demand:** ASKA sells to bike stores which place preorders. The e-bike industry is prone to fluctuations in demand due to disruptive events like the Covid pandemic, high dependence on large component suppliers and seasonal demand changes.
- **Make to order:** ASKA mostly follows a Make to Order production technique, which is atypical in the bike industry. This allows them to be financially robust but creates a direct dependency on suppliers for on-time delivery. They need alternatives in the supply chain.
- **Product with long lifetime:** ASKA bikes are designed with high quality and long lifetime in mind. There is an opportunity for lifetime extension. ASKA bikes will be IoT connected in the future with the opportunity to track their use and their state of health.
- **Lead times as short as possible (control stock level):** Optimize cash flow by applying a "Build to Order" technique. This contrasts to the typical production in the bike industry, which usually focuses big orders in Asia with long lead times.

3.1.2 Stakeholders

Stakeholder	Description
Customer (ASKA)	ASKA as a company and will outsource all manufacturing
Component supplier	Partner that creates components and holds materials needed in their inventory. ASKA manages their supply. E.g., Gilbos (frame), Pulson (battery).
Assembly provider	Partner that assembles the bike. Does not control the supply chain. May be able disassemble as well. E.g., Vlotter.
Tool supplier	Partner that creates a custom fixture for manufacturing frames.
Homologation body	Needed for component and bike manufacturing every time something changes to the bike. Changing suppliers for the same frame design is a grey zone. Changing assembly partner needs to be mentioned in homologation.
Quality Expert	Customer verifies the incoming quality of the supplier.
Production manager	Determines production process at ASKA.

3.1.3 Unforeseen events

Unforeseen event name	Description	Impact	Type	Related to challenge(s)
Supplier cannot (temporarily) deliver	Delays or suspensions of deliveries due to internal disruptions.	Longer lead times, lower OTD	Medium-term	2, 4, 5
Market disruption	E.g. epidemics or pandemics like covid, geopolitical events and recession.	Increased costs of production, shortage of material	Medium-term	3, 4, 5
Changing demands in the bike industry	Difficult to predict consumer trends on products with long life like bikes; seasonal dependency; seasonal demand; introduction of new EU regulations for specific components	Not meeting customer demands	Medium-term	3
Shortage of suppliers/long lead times in supply	Limited known suppliers, causing heavy dependency (single source) and inability to quickly source materials from elsewhere.	Risk stockout/inadequate stock	Medium-term	4, 5
Long lead times for receiving quotations	Suppliers take longer than expected to provide price quotes, slowing down procurement planning.	Project planning and budgeting is delayed, impacting overall production timelines.	Medium-term	2, 4, 5

3.1.4 Goals and acceptance criteria

List of goals (objectives which a system should achieve), with priorities (M - Must have, S - Should have, C - Could have, W - Won't have) and their acceptance criteria.

The needs of ASKA Bike are mainly found in challenges 1 - 4. ASKA will only indirectly address challenge 5 by providing their suppliers with the right information. The needs of ASKA in the RAASCEMAN MaaS System are focused on easily getting quotations and good quality from suppliers.

Goal	Priority	Description	Acceptance criteria	Related to challenge(s)
Goal 1. Flexible production rate, easily introducing second sourceTo be able to adapt to fluctuating demand over the year	M	Frame case: frames are made by one supplier. In moments of changing demand or occurrence by single source supplier, introducing a second will be necessary. Lead time to receive a quotation and the first production batch needs to be decreased.	First contact to be ready to receive first production batch - timing from 9 months to 4 months	1, 2, 3, 4, (5)
Goal 1.1. Find potential suppliers in a network of alternative suppliers	C	Currently, ASKA uses Google. However, a network with different possible suppliers/process will help optimizing this search and easily finding potential suppliers.	Automated internet search	1, 2, 4
Goal 1.2. Fast way to get different quotations	M	Indirectly reduces lead time by getting different quotations in a	From 20 weeks to 4 weeks	1, (5)

Goal	Priority	Description	Acceptance criteria	Related to challenge(s)
		short time base on a digital product description		
Goal 1.3. Compare possible industrial partners to be able to quickly determine who will fill the order	C	Can RAASCEMAN provide a rating? Based on size of the company, how many people are working there, financial situation. different machines and processes available?	Possibility to classify or compare available suppliers based on a specific order	3, 4
Goal 1.4. Evaluation tool for quotations	M	This is about the quotation at the moment of searching for a new supplier. (related to fast way to get different quotations and compare). Evaluate for lead time, quality, on time delivery, cost and carbon footprint.	All evaluation criteria (quality, cost, lead time and environmental impact) taken into consideration	4
Goal 1.5. Test platform with suppliers	C	Involve suppliers in the RAASCEMAN prototype.	Test platform covers the complete quality test of a bike	
Goal 1.6. Ability to change a supplier without the need for homologation of a new supplier	M	Manufacturing process needs to be according to homologation of product (and consequently, manufacturing process). This will be ensured by using a digital product passport.	New quotes does not require a homologation step	4
Goal 2. Product digital twin available to hand over to supplier	M	- Looking for “standardized“ documentation. - Determine the best way to share (frame) tooling/fixture for suppliers (digital and/or physical) (requirement: find a way to share information without the need for an NDA before sharing technical drawings). - Understand the level of detail on which to impose the manufacturing process to (frame) supplier: from product oriented information to process oriented (e.g., ASKA says where the weld must be, the supplier can choose how to do the welding. Supplier now does the entire industrialization to make a quote: how will I make the component, what are the steps, etc.) - Support for information exchange of the following information • CAD file • BOP from CAD file	Covers BOM, BOP, Bill of quality in a common semantic representation understandable by all potential suppliers	1, 2

Goal	Priority	Description	Acceptance criteria	Related to challenge(s)
		Bill of quality – quality checklist (Now it is the CAD file and bill of quality)		
Goal 2.1. Ability to split up the frame production process	M	- For frames, ability to split up the process, e.g., Do surface treatment with different partners. this would still need to be monitored as a single product by the network. - How can suppliers use the network to work together and follow up the different production steps?	Information models of input/output of every production step explicitly described in PDT	3, 4, 5
Goal 2.2. Track lifecycle data of individual bikes through a DPP	M	Use product DPP to determine remanufacturing actions.	DPP is available for test fleet	3

From a business perspective, goal 1 aims at creating a comprehensive network of suppliers in a MaaS system, which will facilitate flexible production and prevent bottlenecks in the supply chain.

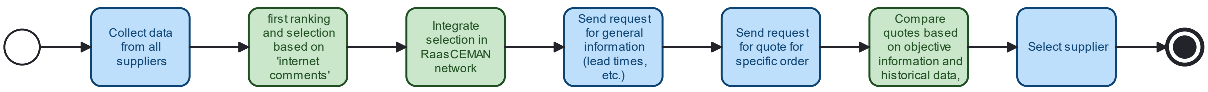
For Goal 2, the business goal is to improve lead time, cost, OTD, with the right quality. Achieving Goal 2 will however not be a guarantee to meet these business goals.

3.1.5 Interaction with the RAASCEMAN system

We provide a number of scenarios for the bike pilot with BPMN diagrams. Green activities are provided by the RAASCEMAN system, blue activities are interactions by the user and purple are activities from the supplier.

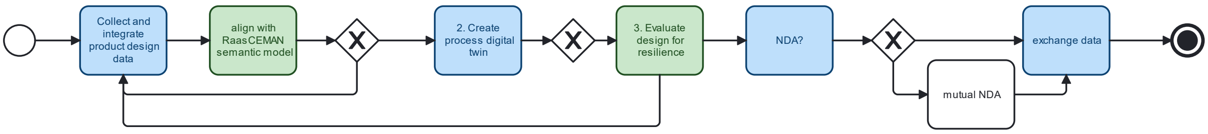
3.1.5.1 Scenario: new supplier

In this scenario, a new supplier is introduced into the MAAS network. After the supplier has been installed, the network will be used to exchange information between supplier and requester. In this way, a quotation can be obtained quickly for a certain service. These quotations can be compared quickly and efficiently in an objective way in the network.



3.1.5.2 Scenario: create digital twin

The scenario begins by collecting and integrating product design data, ensuring alignment with the RAASCEMAN semantic model. Next, a digital twin of the process is created, focusing on identifying the required skills and capabilities. The design is then evaluated for resilience, and if necessary, adjustments are made to the parts' design. It is important to determine what information is protected under NDA and what can be freely shared. Finally, the completed data and design are published on the RAASCEMAN system.



3.1.5.3 Scenario: remanufacturing

The scenario involves updating the digital product passport during the lifecycle of the bike,predicting which components can be used for remanufacturing and determining what their remaining useful life and residual value is, in addition towhat manufacturing operations are needed to use these components as an alternative supply chain. ASKA has models to assess these. Information regarding the quality and timing of components for remanufacturing is then updated in the RAASCEMAN system and can be used as an alternative supply chain. Finally, the supplier recommendation engine compares the remanufacturing scenario with other suppliers to optimize the supply chain and cost.

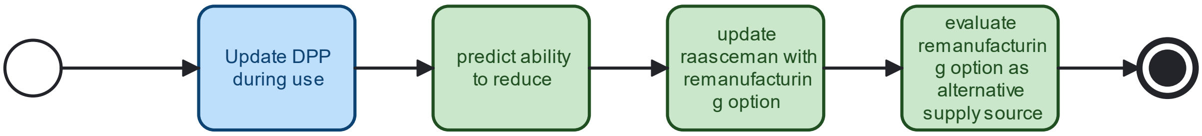


Figure 7: Scenario Remanufacturing

3.1.5.4 Scenario: tracking of manufacturing operations

The manufacturing process begins with the definition of a digitally supported process, „digital twin“. The supplier selects and performs each manufacturing step and adds the required information. This continues until the product is completed, with real-time monitoring of the manufacturing status. The system ensures the completeness of the information for certification, after which ASKA inspects the data and certifies the product. Finally, the homologation body audits the certification and can trace all the relevant data.

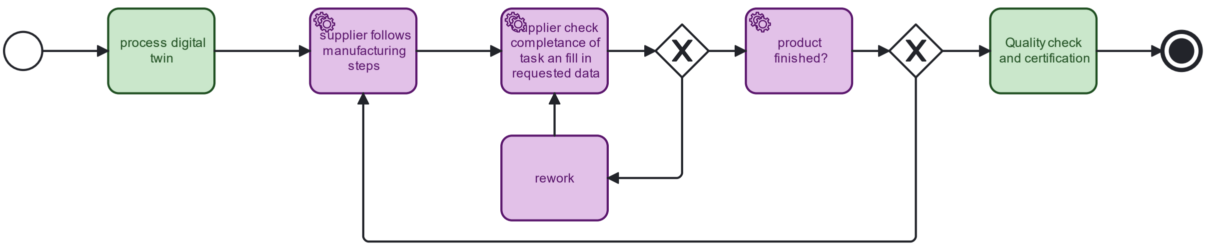


Figure 8: Scenario: tracking of manufacturing operations

3.1.5.5 Scenario: find suppliers working together within network

In this scenario, a supplier of ASKA will use another supplier within the network as a subcontractor. The supplier can use the network to get a quotation for an end product in which different suppliers work together based on the available product information from ASKA, combined with their needs.

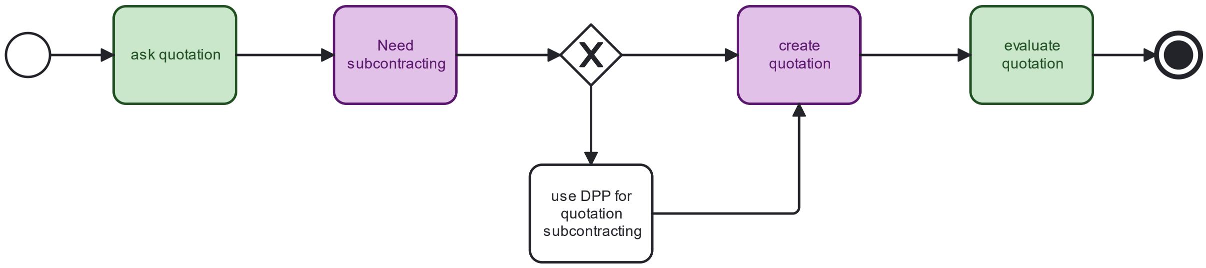


Figure 9: Scenari: find suppliers working together in network

3.2 Users from the automotive pilot

3.2.1 Context and rationale

This pilot at the premises of Continental, Brandys nad Labem, Czech Republic, focuses on operative planning of the production to provide means to the planners to replan production automatically based on the changing conditions at the input (supply) as well as at the output (customer orders and call-offs). The operative planning is done at the level of the Manufacturing Execution System (MES) based on the orders and supplies managed and planned at the level of the Enterprise Resource Planning system (ERP).

A crucial part of this pilot is the availability of a simulation model of the production, which is going to work as a digital twin, i.e. it will be able to accept production orders and execute them. Continental is going to provide access to the data from ERP and MES, which relate to the production planning. It is also going to provide interface to MES, which will allow to execute production orders.

As a result, a planning support tool will be created, which will be evaluated with the simulation model, with a specific instance of MES allowing to control the production simulation. Thus, the existing infrastructure in Continental will be used and connected to. After evaluation, the planning support tool will be evaluated in the real production. In both cases, key users will be involved in the validation and evaluation.

Non-functional requirements

- Each application must pass the Continental internal security approval for the final version of the application to be checked and allowed to be operated on Continental premises.
- Web-based applications are preferred.
- Kubernetes is used to run applications. The computing capacity is outside of Brandys but still on Continental premises.
- As part of the evaluation, the accuracy between the virtual and physical environments will be evaluated too.
- The information exchange for this pilot must comply with the Continental standards for information exchange, which will be considered during the architecture design in task 1.3.
- There is a requirement on high-level availability and robustness in the end. Continuous support is required before final deployment at Continental is done.

3.2.2 Stakeholders

Stakeholder	Description
Planner	Main stakeholder/key user in the future focusing on Operative Production Planning. They say how the operation planning in the production could/should be improved.
Production manager	SCM Customer – Information Level.
Shift leader	Final Customer – Check the fulfilment of the production plan, a shift leader for each production line included.
System integrator	Internal or external to Continental; integration of the modules created in RAASCEMAN to the Continental infrastructure.

3.2.3 Unforeseen events

Unforeseen event name	Description	Impact	Type	Related to challenge(s)
Missing material	Difference between real and to-be supply in the warehouse. Also includes disruptions in supply chain.	- Availability of the production line, replanning is needed – start a variant of production based on the available material. - A substitute supplier is required, or we look in the WIP (Work In Progress) material.	Short-term	4
Bottleneck in intralogistics – may become part of unexpected downtime	- May happen if the AMR fleet management encounters some issues and does not operate as planned. If something breaks down with the AMRs. - May be a long-lasting issue – the AMR system throughput gets blocked gradually until it gets blocked.	Disruption of the supply chain	Short-term	4
Unexpected downtime	- Technical break down - Organizational break down - Intralogistics - AMR Fleet issues	Availability of the production line	Short-term	3
Lack of operators	- Connect to shift planning (special application, where operators are connected and indicate their availability and illness); operators do not want to work overtime. - Calculate in advance when planning the production with the operators available in the application.	Performance - longer cycle time	Medium-term (check each day, may be more often)	3
Call-offs fluctuation	Increase/decrease quantity from OEMs, compare long-term planning. We need to avoid obsoletes.	Can cause obsoletes	Medium-term	3, 5

3.2.4 Goals and acceptance criteria

List of goals (objectives which a system should achieve),, with priorities (M - Must have, S - Should have, C - Could have, W - Won't have) and their acceptance criteria.

Goal	Priority	Description	Acceptance criteria	Related to challenge(s)
Connect to the existing infrastructure (ERP, MES)	M	Use real time data available on Continental existing systems. (MaaS input data)	90% input data available automatically	2
Duration of the replanning	M	Consider also the schedule when the product to be produced and must be delivered to the customer.	From one hour to one minute	3
Be aware of work in progress material out of the line	S	It extends the available stocks after it is disassembled. SAP does not know about the material in the work in progress. Have a link between a BOM and list of equipment – currently it's offline, Conti will consider to connect it to PLM. Not available now.	Optimized OEE (overall equipment effectiveness)	4
Autonomous system without interaction with the planner	S	Include the possibility for the planner to set the priorities Optimization objective: maximization of OEE (can be translated to savings in Labour Cost/Manufacturing Cost): increase availability, decrease change-over time from 8h.	- 80% of production must run without planner interaction. - Decrease the volume of change-over by 30%.	3
Evaluation with the digital twin of the production	M	A Production Lines Digital Twin already exists, and is mandatory to standardize the output/input for operational production plan evaluation.	- All outputs of the planner must be evaluated. Full connection of the MES to the digital twin.	2, 3, 4, 5
Decrease the demands on the main warehouse and maintain inventory levels	C	The warehouse knows in advance what material will be needed based on the known production plan.	Deliver material to shop floor in less than 1 hour compared to 2 hours today.	4
Model adjustment	C	Lessons-learned: self-adaptation of the planning model.	50% accuracy (150 parts difference) After retraining	3

Goal	Priority	Description	Acceptance criteria	Related to challenge(s)
			(model improvement) 80% accuracy.	
Decrease of obsoletes (overproduction)	S	Not to produce more products than really sold.	Decrease by 10%	3, 4
Connect production line to production orders	S	Automatic download of the production orders to the machines so that the operators cannot change the production. There must still be the possibility of manual intervention in case of unexpected errors – can be solved with minute-to-minute planning.	All production orders sent to shop floor.	3

3.2.5 Interaction with the RAASCEMAN system

Basic function MaaS HMI (Preconditions):

- Automatic **data availability** (ERP, MES, Smeny.cz, etc.) + Visualization (KPI, Output, etc.)
- **Planning** -> Quarterly (CutomerEDI)/Monthly/Weekly/Daily (daily work by users)
- **Full Traceability** (Version of the daily plans, store the input data for plan versions, how/what/when)

We provide a few scenarios for the Automotive pilot with BPMN diagrams. Green activities are provided by the RAASCEMAN system, blue activities are interactions by the user.

3.2.5.1 Scenario: missing material

In this scenario, a discrepancy between the actual and expected supply in a warehouse arises. Based on the new correct quantity and the possible arrival date of the material, the RAASCEMAN system recalculates the production plan by postponing the affected orders to a future date.

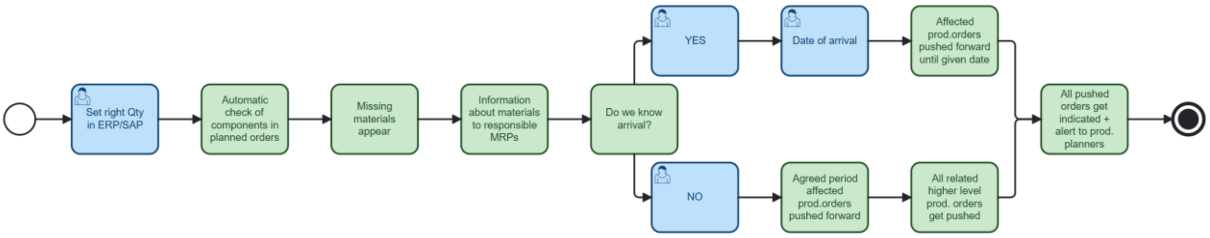


Figure 10: Scenario: missing material

3.2.5.2 Scenario: bottleneck in intralogistics

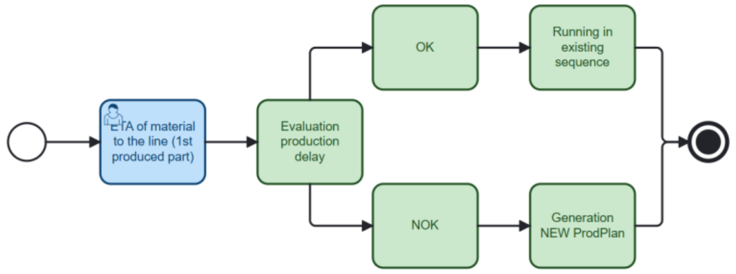


Figure 11: Scenario: bottleneck in intralogistics

3.2.5.3 Scenario: unexpected downtime

When a production line stops, the RAASCEMAN system recognizes the downtime and, based on information from the Maintenance department, predicts OEE (MTTR, MTBF). A new production plan is generated using all available resources. In case of delayed delivery, the customer is informed.

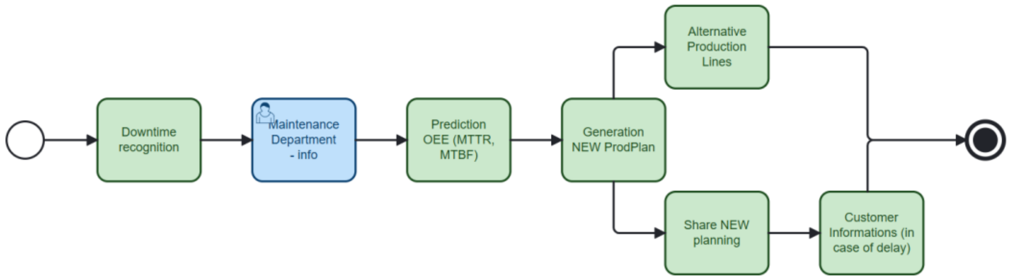


Figure 12: Scenario: unexpected downtime

3.2.5.4 Scenario: lack of operators

Short-term production plans need to be created based on available personnel. Information about operators' availability and their training (which production lines they can operate) is stored in an external system, Smeny.cz. Whenever there is a lack of operators, the production plan needs to be modified accordingly.

Personnel availability needs to be planned based on medium and long-term production plans. When personnel availability is insufficient to cover production plans, alerts pop up and requests are sent to production management.

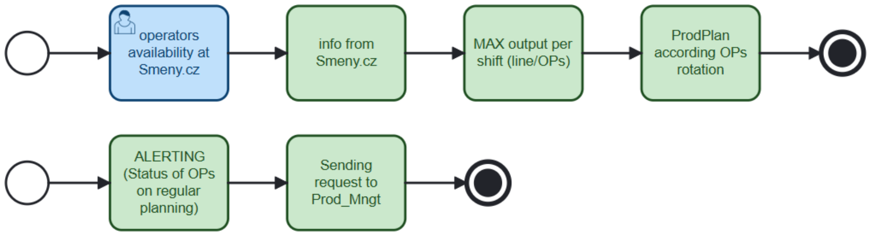


Figure 13: Scenario: lack of operators (Scenario 1 - Short term planning, Scenario 2 - Prediction planning)

3.2.5.5 Scenario: call-offs fluctuation

This scenario describes two situations: first, when the RAASCEMAN system encounters call-offs fluctuations higher than the agreed tolerance during the creation of short, medium, and long-term production plans (planning runs), which are done on a weekly basis; and second, when call-offs fluctuations occur outside of the planning runs.

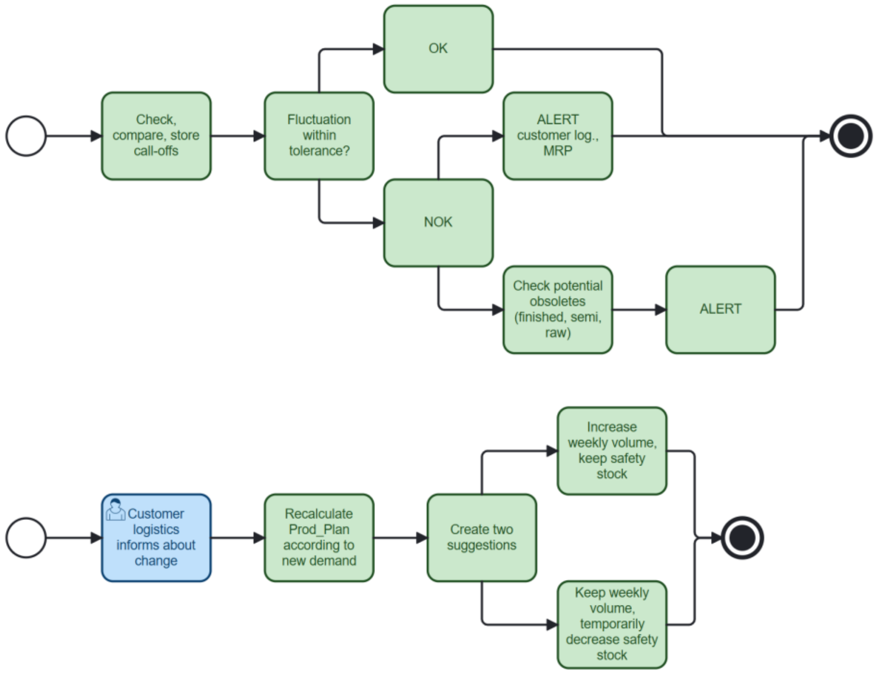


Figure 14: Scenario: call-offs fluctuation (Scenario 1 – Planning Intervals, Scenario 2 - Change minute-to-minute)

3.3 Users from the interconnected pilot line

3.3.1 Context and rationale

The goal of this pilot line is to provide a way to validate and demonstrate the RAASCEMAN system. This pilot represents the MaaS as we envision this in the project. It is not limited by practical barriers like the bike and automotive pilots, and it covers all components of the RAASCEMAN system, thus covering all five challenges.

3.3.2 Stakeholders

Stakeholder	Description
Customer	A participant of the MaaS network who has a need and requests a manufacturing service, e.g., a value-adding activity to manufacture a product or as a cause of suppliers' bottlenecks.
Production manager	A person who plans and organises production schedules.
Production engineer	A person who has knowledge about the domain (production) and provides all the required data for the platform tools and models.
Supply chain manager	A stakeholder, aiming to supplying the organization with all required material and products on time at a low cost and high quality.
Manufacturing service provider	A participant who adds value to the MaaS network, e.g., free capacities to offer machining services.
Quality expert	Customer verifies the incoming quality of the supplier.
Sub-contractor	In case of tier-structure of the MaaS network.
System Integrator	Integrates the service requester and provider into the platform.

Stakeholder	Description
Software service provider	Adds software services to the platform, that can be used by service requester and/or provider
Research partners	The owners of the platform will have their own requirements, namely related to the freedom to operate their pilots as needed, the extensibility of the demonstrators towards other projects, and the alignment with the other research goals, etc.

3.3.3 Unforeseen events

Unforeseen event name	Description	Impact	Type	Related to challenge(s)
Material shortage	Inability of the production's internal facilities to produce the required quantity and quality on time.	- Delays in production. - Delay or breach of contract.	Short-term	5
Supplier cannot deliver (temporarily)	An external event caused by the failure of the supplier to deliver on time, or it may be a logistics delay.	Delays in production. Delay or breach of contract.	Short/ medium-term	5
Production module break down	Any unplanned stoppage of the production equipment.	- Delays in production. - Delay or breach of the contract.	Short-term	5

3.3.4 Goals and acceptance criteria

List of goals (objectives which a system should achieve) with priorities (M - Must have, S - Should have, C - Could have, W - Won't have) and their acceptance criteria.

Goal	Priority	Description	Acceptance criteria	Related to challenge(s)
A common model of a service	M	To ensure interoperability between all the participants in the MaaS network they must share a common understanding and description of services e.g., in form of ontologies, AAS submodels, etc.	- The service model reflects all the necessary information enough for proposing a binding service offer. The model explicitly and in a standard way describes all the aspects of a service, relevant for the services matching, and allowing automatic search for the required services.	1
Common interaction and negotiation rules (protocols)	M	To ensure interoperability between all the participants in the MaaS network they must comply with the	The set of common interaction protocols must enable the automatic search for the required services,	1

Goal	Priority	Description	Acceptance criteria	Related to challenge(s)
		interaction and negotiation rules.	proposition and negotiation of the offers, as well as notification on the offer completion.	
Common connecting technologies	S	There should be a common set of technologies to physically connect to the Maas network (e.g., EDC).	The connectors must ensure the secure and reliable connection to the data spaces respecting European standards and values.	2
Find suitable service providers (capabilities matching)	M	To enable dynamic creation of supply chains, the required and the provided services (production capabilities) must be automatically and reliably compared to each other.	The requested and provided service descriptions are semantically compared, considering various constraints. Based on this comparison, a decision is being made regarding the choice of a particular service.	4
Ensure trust between network participants	M	The MaaS network must provide an instrument to check and audit the participants to ensure trust.	The capability of a service provider to assure the completion of this service is automatically checked. The audit service of the platform provides the assessment of the participants' trustworthiness.	4
The inclusion of human competencies into the provision of manufacturing services.	C	Humans, as participants in production processes, can have different competencies and contribute to the variability of the services provided (manufacturing capabilities).	The system provides services that automatically adapt to the capabilities of the operator involved in the manufacturing process.	5
Reducing the barrier to enter the MaaS network.	M	Offering aids that make it easier for companies to bring their offers into a compliant form.	The system provides services to ease the onboarding of the new user to the network, e.g., the manufacturing services audit service.	5
Provide all necessary information for a human worker for decision support for on-time delivery	M	Provision of realistic and user-friendly instructions to operators, adapted to the setup of the process, the operator's skills, and the shopfloor environment.	User can make decisions based on all involved suppliers in the MaaS network, using all available planning information.	3

3.4 Consolidated stakeholders representing broader European manufacturing

This is a pilot-independent consolidated glossary of terms that we will use in the use cases and user stories of Section 4.

3.4.1 General glossary

- Request: a request for a manufacturing service.
- Service: a result of at least one activity, necessarily performed at the interface between the supplier and customer, that is generally intangible (Source: ISO/IEC Guide 76:2008).
- Manufacturing Service: a service that is requested by a service requestor and that can be offered by a service provider who has the capability and skill to provide such a service.
- Participant: an organization or entity that actively engages within the network, and can act as either a service requester, service provider, or a participant supporting the requestor or provider.
- Network: the collection of participants who take part in the MaaS envisioned by the RAASCEMAN project, and that will be supported by the RAASCEMAN tools and technical bricks created during the project.
- Manufacturing goals: the business level goals that are used to evaluate services. We identified some goals such as lead time, cost, and quality. These goals have associated KPIs.
- Risk: defined in terms of meeting manufacturing goals.
- Unforeseen event: the set of disruptive, unexpected occurrences that can cause problems or bottleneck to achieve the goals and priorities set by the participants of the MAAS network (see Section 3.4.4 for more info).
- Common Information Model (CIM): a standardized framework developed to represent, model, and exchange data about complex systems to enable a common understanding of mandatory (data) information that will be exchanged in the MaaS network.
- Temporary make/buy decision: a strategic and operational choice to either produce a product or service internally (make) or procure it from an external supplier (buy) for a limited or short-term period in response to a specific, temporary circumstances rather than as a long-term strategic direction.

3.4.2 Tools of the RAASCEMAN system

Tools developed during RAASCEMAN	Challenges Addressed
Capability, Skill and Service (CSS)-model	Challenge 1
Product Digital Twin (PDT)	
Intra-company Infrastructure	Challenge 2
Cross-company Infrastructure	
Impact Prediction Tool	Challenge 3
Decision Support Tool	
On-boarding Guide/tool to MaaS	Challenge 4
Supplier Audit Tool	
Supplier Recommendation Tool	

Tools developed during RAASCEMAN	Challenges Addressed
Capability Matching Tool	Challenge 5
Dynamic Planning and Scheduling Tool	
Dynamic Execution Tool	

3.4.3 Stakeholders

This section provides the list of all stakeholders participating in the RAASCEMAN MaaS system and their description, including a use case independent consolidation of the above pilots.

#	Stakeholder	Description
1	Manufacturing service requester	The company who has a need and requests a manufacturing service, e.g., a value-adding activity to manufacture a product or as a cause of suppliers' bottlenecks.
1.1	Customer	A manufacturing service requester who approves or rejects the manufactured goods and pays the service provider.
1.2	Manufacturing service requester's Product Engineer	The department or personnel at the customer's side who designs the product for manufacturing and assembly.
1.3	Manufacturing service requester's Quality Expert	The department or personnel at the customer's side who verifies the incoming quality of the supplier's goods.
1.4	Manufacturing service requester's Production Manager	The department or personnel at the customer's side who focus on operative production planning. They say how the operation planning in the production could/should be improved.
1.5	Manufacturing service requester's Shift Leader	The department or personnel at the customer's side who check the fulfilment of the production plan, a shift leader for each production line included.
1.6	Manufacturing service requester's Supply Chain Manager	The department or personnel at the customer's side who aim to supply the organization with all required material and products on time at a low cost and high quality.
1.7	Manufacturing service requester as a MaaS network participant	A manufacturing service requester who participates in the MaaS network and agrees to create a profile with their credentials to be visible in the network.
2	Manufacturing service provider	The company who responds to a manufacturing service request, with the relevant capabilities and promise of delivery.
2.1	Component supplier	A manufacturing service provider who creates components for the customer and hold materials needed for this in their inventory.
2.2	Assembly provider	A manufacturing service provider who assembles the product for the customer. Do not control the supply chain. May be able to do disassembly as well.
2.3	Tool supplier	A manufacturing service provider who creates customized tools and fixtures required for the manufacture of the designed parts by the customer.
2.4	Homologation body	Needed for component and bike manufacturing every time anything changes to the bike. Changing supplier for same frame design is a grey zone. Changing assembly needs to be mentioned in homologation.
2.5	Sub-contractor	A supplier to the main manufacturing service provider. They possess specialized skills lacking at the main supplier's end.

#	Stakeholder	Description
2.6	Manufacturing service provider’s Quality Expert	The department or personnel at the manufacturing service provider's side who verifies the incoming quality of the supplier's goods.
2.7	Manufacturing service provider’s Production Manager	The department or personnel at the manufacturing service provider's side who focus on operative production planning. They say how the operation planning in the production could/should be improved.
2.8	Manufacturing service provider’s Shift Leader	The department or personnel at the manufacturing service provider's side who check the fulfilment of the production plan, a shift leader for each production line included.
2.9	Manufacturing service provider’s Supply Chain Manager	The department or personnel at the manufacturing service provider's side who aim to supply the organization with all required material and products on time at a low cost and high quality.
2.10	Manufacturing service provider as a MaaS network participant	A manufacturing service provider who adds value to the MaaS network, e.g., free capacities to offer machining services.
2.11	Manufacturing service provider's Logistics Provider	The department or personnel at the manufacturing service provider's side who provides logistics services for realizing requester/provider.
3	MaaS network provider	The company or team who create new profiles in the MaaS network and maintain it for smooth functioning.
3.1	System integrator	The MaaS network provider who integrates the service requester and provider into the platform.
3.2	Software service provider	The MaaS network provider who adds software services to the platform, that can be used by service requester and/or provider
3.3	Research partners	The owners of the network who will have their own requirements, namely related to freedom to operate, extensibility of the demonstrator towards other projects, alignment with research partners‘ goals, etc.

3.4.4 Unforeseen events

List all unforeseen events of this pilot, including a use case independent consolidation of the above pilots.

Unforeseen event name	Description	Impact	Type	Related to challenge
Missing material	Difference between real and to-be supply in the warehouse. Includes also disruptions in supply chain.	Availability of the production line, replanning is needed – start a variant of production based on the material, which is available. A substitute supplier is required, or we look in the WiP material.	Short-term	4
Bottleneck in intralogistics – may become part of	- May happen if the AMR fleet management encounters some issues and does not operate as planned. If something breaks down with the AMRs.	Disruption of the supply chain.	Short-term	4

Unforeseen event name	Description	Impact	Type	Related to challenge
unexpected downtime	- May be a long-lasting issue – the AMR system throughput gets blocking gradually until it gets blocked.			
Unexpected downtime	- Technical break down - Organizational break down - Intra-logistics - AMR Fleet issues	Availability of the production line.	Short-term	3
Lack of operators	- Connect to shift planning (special application, where operators are connected and indicate their availability and illness); operators do not want to work overtime. - Calculate in advance when planning the production with the operators available in the application.	- Performance - longer cycle time	Medium-term	3
Call-offs fluctuation	Increase/decrease quantity from OEMs, compare long-term planning. We need to avoid obsoletes.	Can cause obsoletes.	Medium-term	3, 5
Supplier cannot deliver (temporarily)	Delays or suspensions of deliveries due to internal disruptions.	Longer lead times, lower OTD.	Medium-term	2, 4, 5
Market disruption	E.g. epidemics or pandemics like covid, geopolitical events, recession. Difficult to predict consumer trends on products with long life. Newlike bikes/new EU regulations for specific components.	Increased costs of production, shortage of material.	Medium-term	3, 4, 5
Long lead times in supply	Limited known suppliers, causing heavy dependency and inability to quickly source materials from elsewhere	Risk stockout/ inadequate stock.	Medium-term	4, 5
Long lead times for receiving quotations	Suppliers take longer than expected to provide price quotes, slowing down procurement planning	Project planning and budgeting is delayed, impacting overall production timelines.	Medium-term	2, 4, 5

3.4.5 Key performance indicators

The KPIs used in the RAASCEMAN project are defined in WP1 as part of Task 1.2 and will be detailed in via deliverable D1.2.

4 Use Cases and user stories

This section is the outcome from a first phase of requirements analysis. From the information of Section 3, we translate the high level user needs to sector independent use cases and user stories for the RAASCEMAN MaaS system. This means that the system adheres to the requirements of the three pilots, as well as the broader manufacturing sector.

We first introduce the high level use cases and present then user stories according to the five challenges of Section 2.

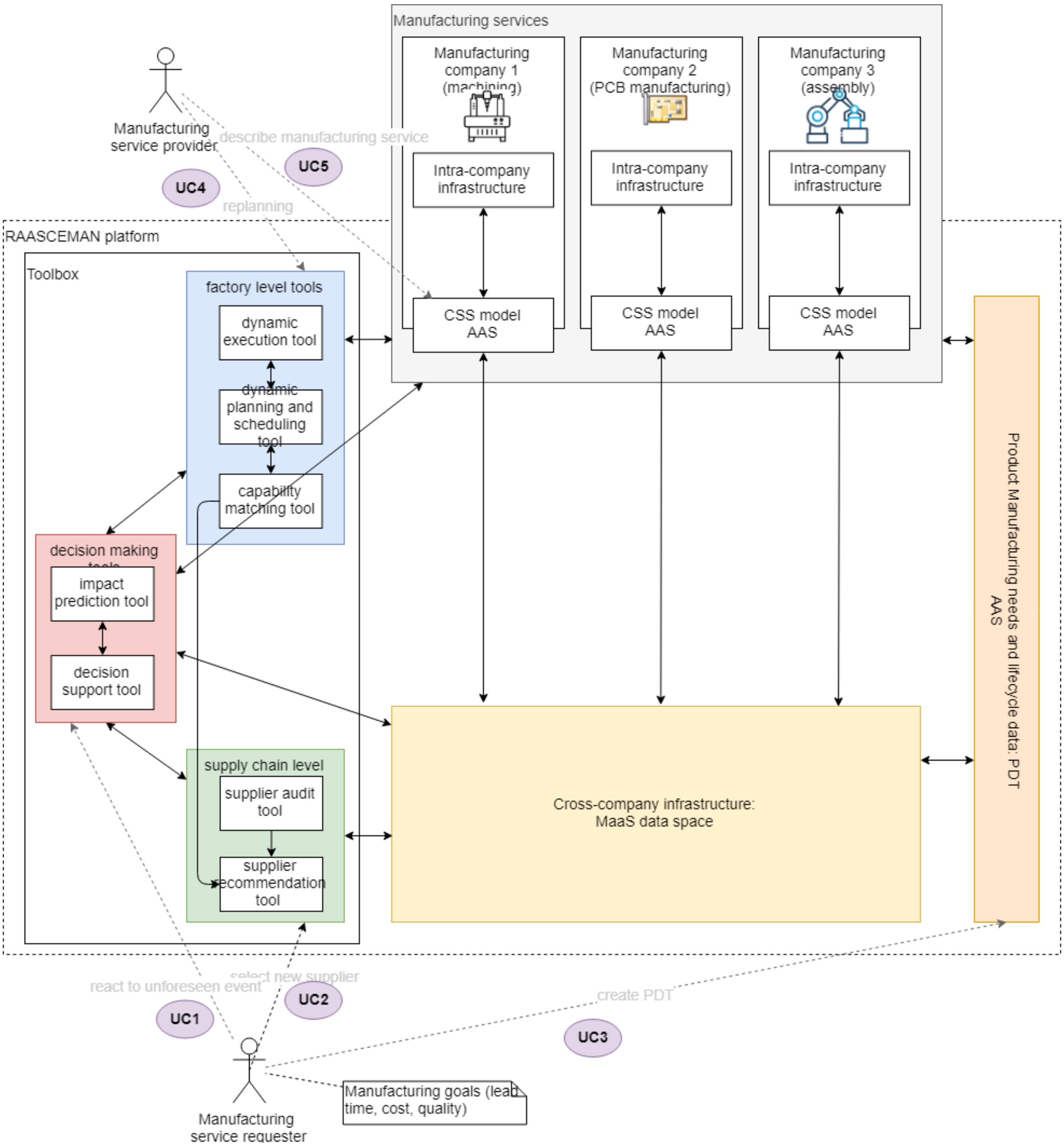


Figure 15: Overview of the RAASCEMAN platform, with its main use cases.

Figure 15 shows the high level use cases and how they interact with the RAASCEMAN platform. A high level breakdown of the RAASCEMAN platform is given, showing its tools (left, challenge 3, 4, 5), integration with manufacturing systems (top, challenge 1, 2), integration of the product digital twin (right, challenge 1), and the cross company infrastructure (bottom, challenge 2). The architecture of the RAASCEMAN platform will be specified in D1.3. This figure serves as a blueprint for structuring use cases and user stories.

4.1 High level use cases

These use cases elaborate on the main goals of the RAASCEMAN platform, in order to provide better understanding of the functions of the system and how it is intended to be used. A use case can refer to several user stories (US) (elaborated further in this section), and other use cases (UC).

4.1.1 Use case 1: React to unforeseen events

Use case name	**React to unforeseen events**
Use case ID	**UC1**
Author	Bart Meyers
Related user story	US3
Challenge	Challenge 3: Enabling human decision maker to react to unforeseen events
Primary actor	Production manager
Secondary actor	
Goals	React to medium-term unforeseen events
Preconditions	System has been set up
Triggers	Supply chain network has been defined

This use case, which diagram shown in Figure 16 details how manufacturers (requesters and providers) can use the system in case of an unforeseen event. The use case shows how the user can get an immediate high-level recommendation (new supplier or replan) based on the information that exists.

After the user logs in, the use case continues with interaction with the impact prediction tool. The starting point is an unforeseen event. The user can select from a list of unforeseen events, from the model trained with company's historical dataset, to adapt specific behaviours of the specific environment. By selecting a specific event, for example a "expected arrival time of a raw material order", or a "machine breakdown" the user will be able to foresee the likelihood of different potential values, while also the expected one. On top of that, a prediction on the impact that each potential result would have on the company's performance, e.g. "delay of production orders" or "reduction in OEE" will be the basis for making quantitative decisions for each scenario. The results will be visualized using histograms, distributions, and variation graphs, previewing the potential scenarios. In the presence of missing information, or connection absence, the user will provide the required information from a GUI access. In addition, the correlation of different events and thus risk for cascading events will be also evaluated within the tool.

Based on the overview provided by the impact prediction tool, the user can use the decision support tool to create potential strategies for dealing with the event. These scenarios may represent make or buy decisions, and may include specific constraints or preferences (e.g., preferred supplier, KPIs, etc.). For each scenario, the decision support tool will search for data that is needed to assess the scenario. If data is missing, the user is prompted to provide their estimates. Based on data, the decision support tool will use the impact prediction tool to calculate the impact of each scenario. The results are visualized so that the user can compare them in terms of manufacturing goal KPIs. This allows the user to choose a high level strategy for dealing with the unforeseen event, based on available data and assumptions. Depending on the choice, the user will continue with the outcome of this tool in use case 2 (Select new Supplier) and/or to use case 4 (Replanning) for realizing the chosen strategy.

Flow:

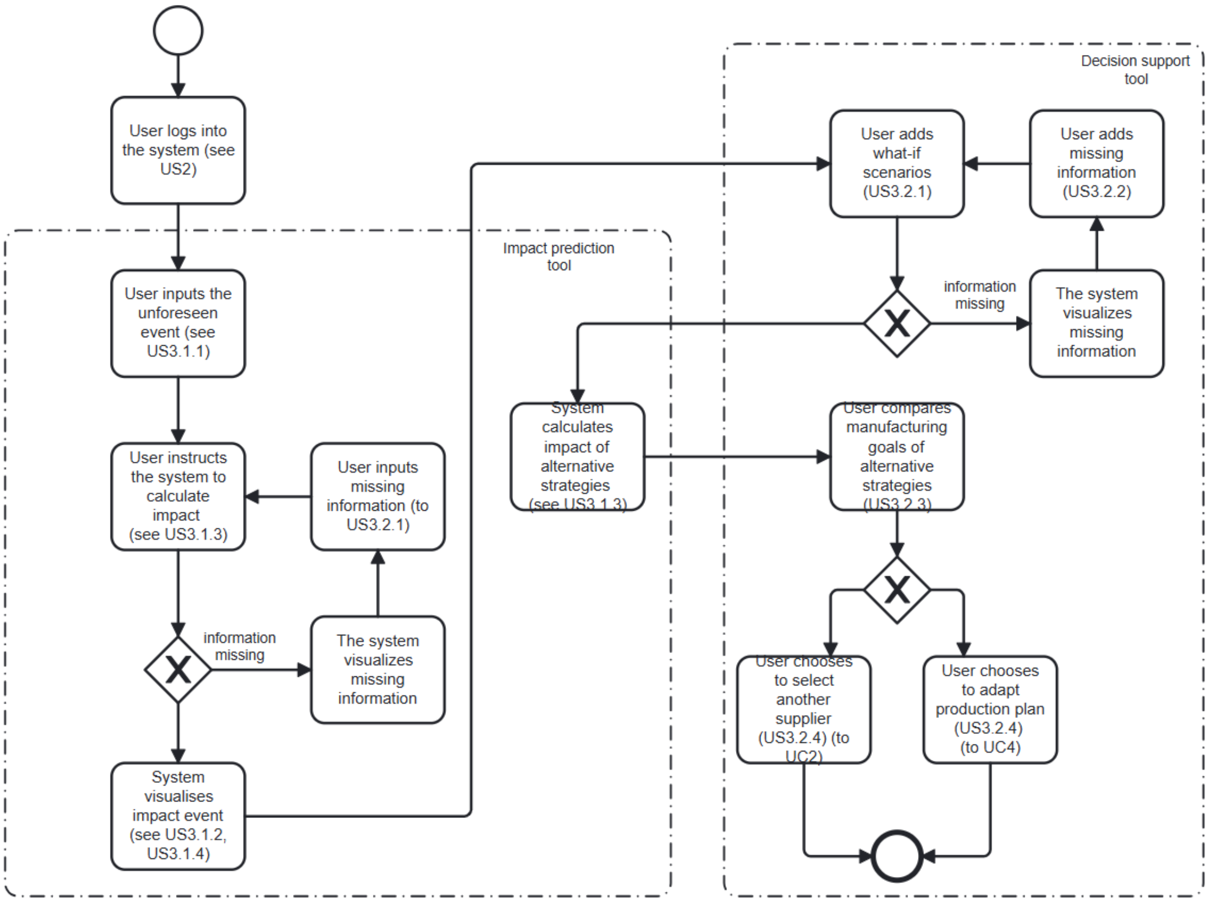


Figure 16 BPMN diagram of the use case UC1

4.1.2 Use case 2: Select new supplier

Use case name	**Select new supplier**
Use case ID	**UC2**
Author	Maithili Deshmukh, Aleksandr Sidorenko
Related user story	US4
Challenge	Challenge 4: Enable companies to swiftly find suppliers and ensuring trust and reliability
Primary actor	Production manager
Secondary actor	Supplier
Goals	Assess and select a new supplier who meets project requirements for cost, quality, and delivery times

Use case name	Select new supplier
Preconditions	1) The system has been setup 2) The model of the required service has been defined (UC5) 3) Requirements, budget and timeline are established
Triggers	There is a need for a new supplier due to unforeseen events

The process shown in Figure 17 outlines a systematic workflow for selecting a supplier through a MaaS system, ensuring efficiency and adaptability to different outcomes. It starts with the production manager entering the service requirements into the system, which then prepares a standardized service request. A request for quotation is sent to the MaaS network, and the recommendation engine identifies potential suppliers by matching the required services with those available on the network. The request is then directed only to suppliers whose services match the requirements, ensuring a focused and efficient outreach.

Suppliers evaluate the request internally and submit their quotations if they can meet the service requirements. The offers are then reviewed by the audit tool, which assesses their ability to deliver the specified service. These quotations, together with the reliability scores provided by the audit tool, are processed by the recommendation engine. Based on the suppliers' capabilities and scores, the production manager selects the most suitable supplier, completing the process.

In cases where no matching services are found in the network after the request for quotation, the system notifies the production manager. A new impact analysis is performed using the Impact Prediction Tool, and the Decision Support Tool devises new strategies to address the situation. This alternative flow ensures that unforeseen challenges are faced with actionable insights and strategic options.

If, after evaluating the request, suppliers do not respond, the process reverts to the previous alternative flow. The system notifies the production manager, performs an impact analysis and uses the decision support tool to develop alternative strategies. This ensures continuity and proactive problem solving in the absence of supplier responses.

In addition, if the audit tool rejects a submitted quotation, it notifies the supplier of the rejection, ensuring transparency and accountability. This rejection triggers feedback to the supplier and maintains the integrity of the evaluation process.

Overall, this workflow integrates automation, recommendation engines and decision support tools to optimize supplier selection. It ensures that the process remains robust, adaptable and efficient, with systematic solutions for both expected and unexpected scenarios.

Flow:

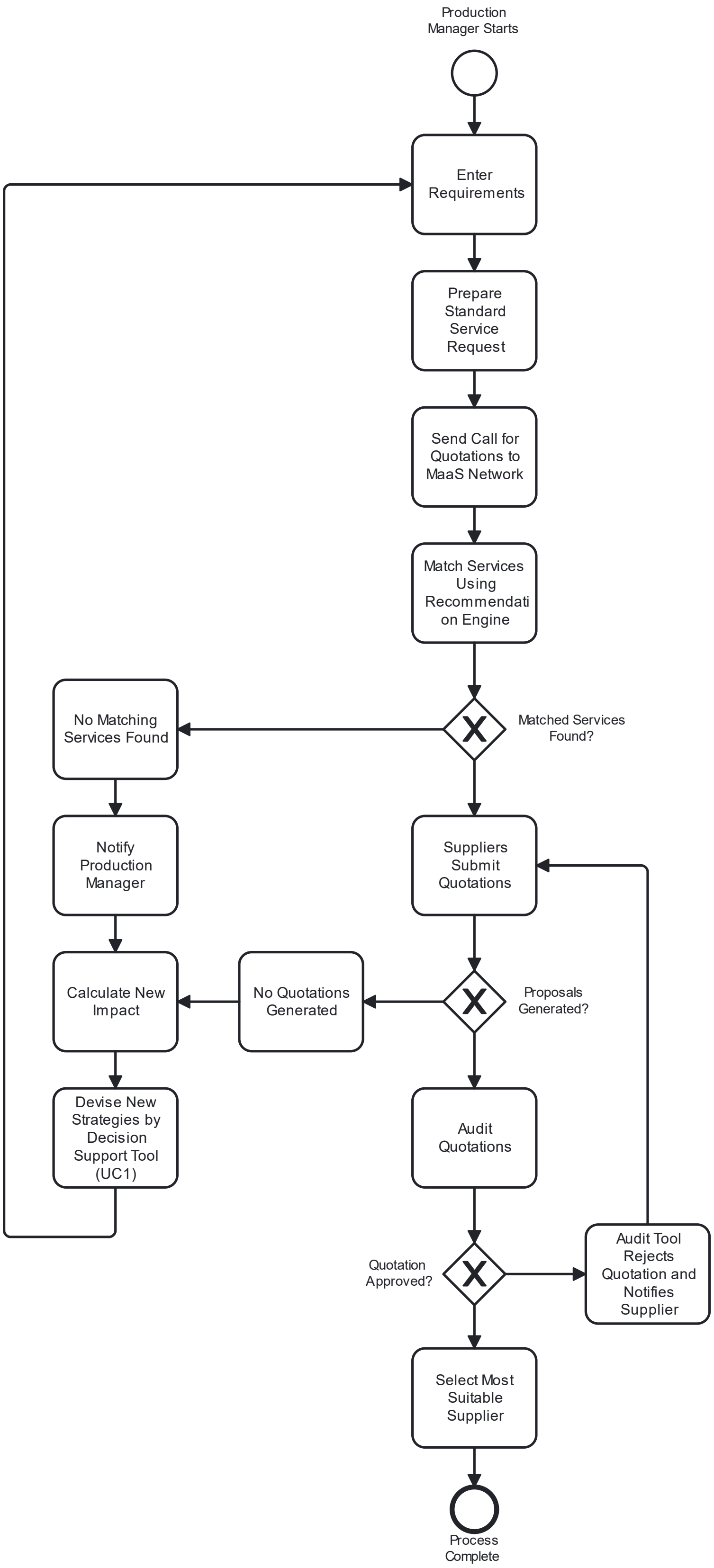


Figure 17 BPMN diagram of the use case UC2

4.1.3 Use case 3: Create PDT

Use case name	**Create Product Digital Twin (PDT)**
Use case ID	**UC3**
Author	Maithili Deshmukh, Evangelos Xanthakis, Kunal Suri
Related user story	US1
Challenge	Challenge 1: Common semantic representation, 2: Intra & cross-factory communication based on standards
Primary actor	Design Engineer
Secondary actor	Network Participant
Goals	To create a digital platform supporting information exchange within the factory and across the network, utilizing industrial standard
Preconditions	Complete product design data, BoM, BoP are available
Triggers	Product design is finalized

The process flow depicted in this section and shown in outlines steps needed by a design engineer and other participants of a MaaS network to create Product Digital Twin(s), wherein they will integrating the Asset Administration Shell (AAS) and several different Digital Twin technical bricks together. This process encompasses steps starting from gathering product-related data ending with integrating the AAS into various manufacturing systems, ensuring seamless data sharing through frameworks like GAIA-X and the International Data Spaces (IDS).

The process will start with the design engineer collecting comprehensive data related to the product's design and performance metrics. They will utilize the collected data to create a Digital Twin in the form of an Asset Administration Shell, encapsulating all relevant information and functionalities of the physical asset. Next, (standardized) AAS will be deployed across different manufacturing systems within the MaaS network, ensuring interoperability and standardized communication. This standardized AAS will facilitate sharing of data seamlessly across various manufacturing systems through frameworks such as GAIA-X and IDS, promoting secure and efficient data exchange.

Flow:

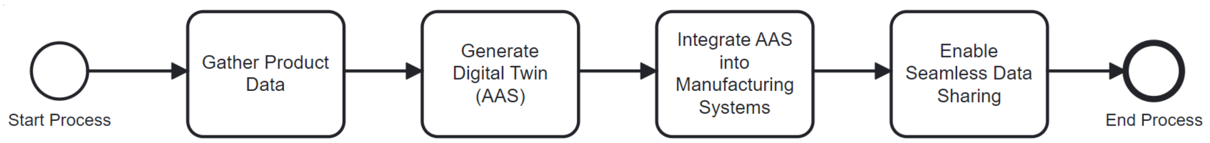


Figure 18: Flow of use case to create Product Digital Twin

4.1.4 Use case 4: Replanning

Use case name	**Replanning**
Use case ID	**UC4**
Author	Pavel Burget
Related user story	US5
Challenge	3, 5
Primary actor	Production manager
Secondary actor	Production Planner, Supply Chain Manager
Goals	To efficiently adapt production plans in response to unforeseen events such as supply chain disruptions, machinery breakdown, or sudden changes in market demand.
Preconditions	- The production system is fully operational. - The system has access to real-time data on inventory, orders, and production capacity. - All relevant actors have access to the system and are trained to use the replanning tools.
Triggers	Detection of an unforeseen event that impacts production schedules or output.

In this use case, which diagram is shown in Figure 19 the primary actor, the Production Manager, is responsible for maintaining the smooth operation of the production line. The use case begins when the system detects a potential disruption, such as a supply chain delay, equipment failure, or a sudden change in market demand that could impact production schedules or output.

Upon detection of the disruption, the system immediately notifies the Production Manager. This notification serves as a trigger for the Production Manager to assess the impact of the disruption on the current production processes. Based on this assessment, the Production Manager decides to initiate the replanning tool within the production management system. This tool is designed to analyze current production data, including available resources, ongoing tasks, and any constraints that might affect production.

The replanning tool then processes this data and proposes several alternative production schedules. Each alternative aims to minimize the disruption's impact while maintaining production efficiency and output quality. The Production Manager reviews these alternatives, considering factors such as resource utilization, delivery timelines, and overall production costs.

After evaluating the options, the Production Manager selects the most feasible alternative. This selected plan is then implemented into the production schedule. The system updates accordingly and sends notifications to all relevant stakeholders, including the Production Planner and Supply Chain Manager, informing them of the changes and ensuring that everyone is aligned with the new production strategy.

If the replanning tool fails to provide a feasible alternative, or if the Production Manager rejects all proposed plans, the scenario extends to involve manual intervention. In such cases, the Production Manager may consult directly with the Production Planner and the Supply Chain Manager to devise a manual replanning strategy. This collaborative approach helps to develop a customized solution that the system might not have initially considered.

Once a new plan is agreed upon manually, the system is updated to reflect these changes, ensuring that production can continue with minimal downtime and that the impact on delivery schedules and product quality is effectively mitigated.

The success of this use case relies on the system's ability to rapidly process data and provide actionable alternatives, as well as the stakeholders' responsiveness and decision-making capabilities. It is assumed that the system has access to accurate and timely data and that all stakeholders are committed to a collaborative and responsive approach to production management.

This use case is executed as needed, triggered by the occurrence of unforeseen events that pose a risk to production continuity. Its successful execution ensures that production adapts quickly to challenges, maintaining operational efficiency and customer satisfaction.

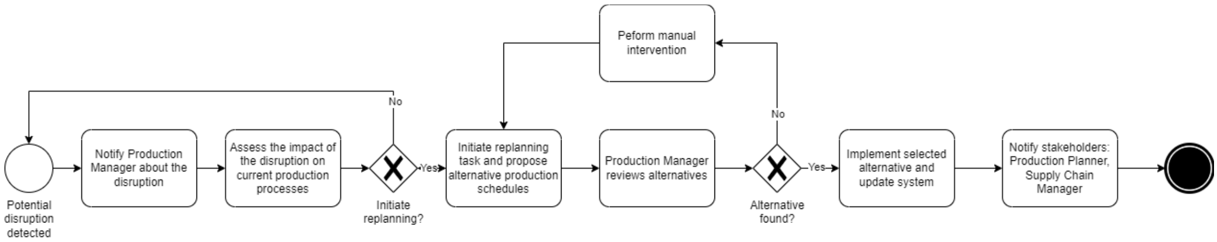


Figure 19 BPMN diagram of the use case UC4

4.1.5 Use case 5: Describe manufacturing service

Use case name	**Describe manufacturing service and add it to the MaaS network**
Use case ID	**UC5**
Author	Maithili Deshmukh, Patrick Kremser
Related user story	US1
Challenge	Challenge 1: Common semantic representation
Primary actor	Supplier
Secondary actor	IT specialist
Goals	To accurately represent the manufacturing service on the MaaS network, making it easily discoverable to potential customers
Preconditions	Access to the MaaS network interface or API is available
Triggers	Positive decision to expand service visibility by listing it on the MaaS network

The process flow depicted in outlines the submission of manufacturing information to the MaaS network, enabling suppliers to efficiently share detailed information about their manufacturing capabilities. The process starts with the supplier uploading relevant information or documentation, such as manuals, technical drawings, 3D models of machines or machined parts, or even machine codes such as G-code. Once this data is uploaded, the supplier uses the platform tool to extract detailed manufacturing information, including specifications, pricing and lead times, to ensure that all the necessary details are available for processing.

The extracted information is then submitted to the MaaS network via an online form or API integration. Once submitted, the listing undergoes a review process to ensure accuracy and completeness. Any necessary adjustments or refinements to the extracted manufacturing details are made by the supplier during the editing phase. Once all corrections are completed, the manufacturing information is published on the MaaS platform and made available to potential customers.

If technical issues occur during the submission process, the workflow moves to a troubleshooting phase. In this alternative flow, an IT specialist identifies and resolves the issues, such as connectivity problems, to ensure that the submission can proceed successfully. After troubleshooting, the process continues as normal, allowing the information to be reviewed, edited and published.

This structured workflow ensures the seamless and accurate integration of manufacturing data into the MaaS platform, increasing the reliability and efficiency of the overall system.

Flow:

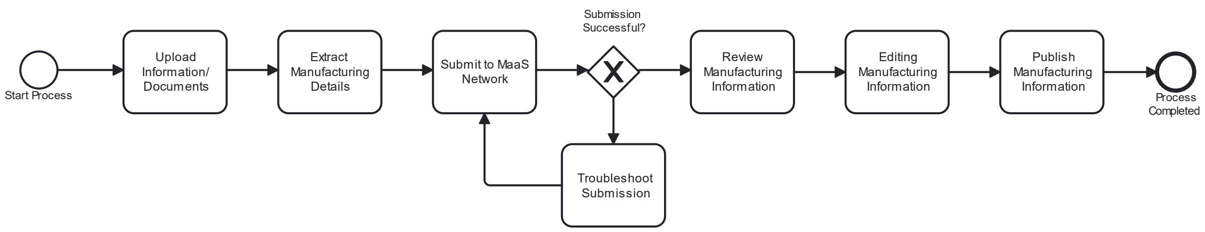


Figure 20: Flow for use case "describe manufacturing service"

4.2 Challenge 1: Common semantic representation

For an interaction between a customer and a producer, a standardized description of their services must be established to ensure a common semantic representation. This common framework is essential to enable data exchange between the parties and to integrate them into the RAASCEMAN network. To participate in the network, each member can publish its services using a common semantic framework to enable interoperable communication both within and between factories. (Challenge 2) This framework also supports communication during unforeseen events, helping participants to respond to new situations in a timely manner. (Challenge 3) In addition, it enabled swift communication between all members within the RAASCEMAN network to find suppliers with high trustworthiness (Challenges 4) and to create offers or adapt the production plan. (Challenge 5)

> ***System level user story US1**: As a manufacturing service requester/provider, I can describe my manufacturing request/services in a common way, so that I am compatible with the platform and can be a participant in the network.*

To interact within the RAASCEMAN network, each service provider must describe its own services to all participants. For this description a common semantic representation for each participant is needed to have the same vocabulary for all participants.

***Epic user story US1.1:** As a manufacturing service provider, I can describe my service using the CSS model, so that it can be understood by network participants.*

As the factory evolves over time, service providers can enhance the capabilities and skills of each station within the network by selling or buying machines and tools, and by improving the skills of the workers through workshops and training.

***User story US1.1.1**: As a manufacturing service provider's production manager, I can view the machines I have provided in the common information model and edit the capabilities and skills of each machine.*

In order to show the trustworthiness and the current production situation of a service provider, parameters can be provided that give an idea of the trust and reliability for a new customer. These indicators can help a service requester to choose the best service provider. (Challenge 4)

***User story US1.1.2**: As a manufacturing service provider's production manager, I can provide KPIs for manufacturing goals as dynamic parameters, in terms of the current situation in my factory, so that I can give better indicators to potential manufacturing service requesters.*

To reduce the time between negotiations between customers and suppliers, it would be helpful to filter the right offer with a few options such as cost, CO_2 footprint or delivery time. In addition, the search can be automated to reduce negotiation time as well.

***User story US1.1.3**: As a manufacturing service provider, I can provide models with different options for negotiation (e.g., rush order for higher cost or not), so that the system can automate the negotiation phase.*

In order to have traceability about the production process of the product, the service provider can store its production data such as duration, costs, CO2 footprint, energy composition in the common information model. This allows the supplier to have a better overview of its production efficiency. With access to this information only for the requester of the product, the customer can get the state of the production process.

***User story US1.1.4**: As a manufacturing service provider's production manager, I can store my production data, such as duration, costs, CO2 footprint, energy consumption, in the common information model, and this data is only available to the requester.*

To achieve interoperability in different production lines, the storage of information (data and data structures) should be in a common semantic representation, you need a standardized exchange format and a structured semantic classification standard that is internationally accepted to specify the production asset.

***User story US1.1.5**: As a manufacturing service provider (engineer & production manager), I can use the asset administration shell with the semantic Ids based on the ECLASS id, so that my information is interoperable.*

Supporting the trust and reliability tool in the network it is useful to store every quotation inside common information model for tracking the offer and result/invoice how accuracy was the quotation.

***User story US1.1.6**: As a manufacturing service provider, I can store quotations on the common information model.*

Describing the product for all participants in the RAASCEMAN network in such a way that the service requester can describe the required properties, and the service provider can understand the required properties of the part to be manufactured. With this description, the possibility of misunderstandings between the service requester and the service provider is reduced to almost zero.

> ***Epic user story US1.2**: As a manufacturing service requester/provider, I can describe information that is necessary for MaaS in a common and efficient way using a (standardized) product digital twin, so that the information for manufacturing is available to the different stakeholders as needed.*

By uploading the production information to the RAASCEMAN network, the service requester gets an overview of all the necessary properties that all participants can see and use to create a quotation for the product. If some properties do not meet the requirements of the requester's side, the requester can change the information to the correct ones.

> ***User story US1.2.1**: As a manufacturing service requester's Product Engineer, I can view the products I have requested in the common information model and edit the required capabilities and skills for the manufacturing of each product.*

To generate a product planning shortlist of potential suppliers, parameters can be used to filter suppliers by production goals.

> ***User story US1.2.2**: As a manufacturing service requester, I can provide my manufacturing goals, such as duration, costs, CO2 footprint and energy consumption, in the common information model.*

The requester can specify a required service for a specific property of the product to be manufactured, such as this surface needs to be milled by CNC tool machine.

> ***User story US1.2.3**: As a manufacturing service requester, I can specify the skills needed for my request in terms of the CSS model, so that it can be matched with services in the network.*

To avoid misunderstandings between all participants within the RAASCEMAN network. I can publish the product in a standardized exchange format with a structured semantic classification standard for services.

> ***User story US1.2.4**: As a manufacturing service requester's Product Engineer, I can specify my product as an asset administration shell (AAS) model with an ECLASS id.*

To receive all the necessary data about the production process from the supplier, the requester can select the information that is important to him.

> ***User story US1.2.5**: As a manufacturing service requester's Product Engineer, I can specify necessary product information like BoM, BoP, quality information etc. with the CSS model.*

The requester can only see the progress of the requested product if the service provider can add information to the digital representation of the product.

> ***User story US1.2.6**: As a manufacturing service provider, I can add information on a product instance level (digital product passport), so that progress on manufacturing can be tracked as requested.*

4.3 Challenge 2: Intra- and cross-factory communication based on standards and European values

Sharing of internal data should be achieved using standardized methods in order to ensure compatibility with the platform. In this way the necessary data will be available for the various manufacturing services.

> ***System level user story US2****: As a manufacturing service requester/provider, I can use an infrastructure in order to share internal data in a standardized way, so that the services are supported with the right data flow.*

A service provider can upload AAS models to the RAASCEMAN network through an AAS API, ensuring unified and reliable data management. The information within the AASs of all the service providers will be available to the service requester in order to decide which is the most suitable.

> ***Epic user story US2.1****: As a manufacturing service requester/provider, I can use the intra-company infrastructure to connect my AAS models to my internal software systems, so that it is a single source of truth for my factory data.*

The platform supports standardized communication protocols (OPCUA, MQTT, REST etc.) for linking AAS models with the field level.

> ***User story US2.1.1****: As a manufacturing service requester/provider, I can use standardized protocols to link my AAS models with the shopfloor.*

Useful information provided from the intra-company infrastructure like analytics reports, production data and historical data can be used for optimizing the production process.

> ***User story US2.1.2****: As a manufacturing service requester/provider, I can use the information generated from the intra-company infrastructure link (i.e. for production planning, analytics).*

Collaboration and exchange of data between the manufacturing stakeholders is achieved from the cross-company infrastructure. This way the companies can act both as service providers and requesters.

> ***Epic user story US2.2****: As a manufacturing service requester and provider, I can use the cross-company infrastructure to exchange information with other participants of a MaaS network.*

The details of the provided/requested service constitute sensitive and private information, so different level of access to data can be granted to each participant in order to ensure digital sovereignty.

> ***User story US2.2.1****: As a manufacturing service requester and provider, I can use the cross-company infrastructure to retain the authority (i.e., data sovereignty) to which participant I can provide my data.*

> ***User story US2.2.2****: As a RAASCEMAN components, I can use the intra-company infrastructure to access cross-company information*

A manufacturing service is able to register its company to the cross-company network and contribute available assets.

> ***User story US2.2.3****: As a manufacturing service provider, I can add my company and information as a "participant" to the cross-company network.*

4.4 Challenge 3: Enabling human decision maker to react to unforeseen events

Triggered by an unexpected event, a tool will provide an overview of the impact of this event and will support decision making. The high level manufacturing goals (OEE, OTD, throughput, cost) of the user will be the drivers of the decision. The decision making process makes use of historical and live data, but translates this to the user in terms of their manufacturing goals.

> ***System level user story US3****: As a manufacturing service requester/provider, I can make an informed decision in case of an unforeseen event, so that I can meet my manufacturing goals*

In the greater sense, ideally for a manufacturer it would play a significant role to successful decision making, if the supply chain and production risks could be predicted and evaluated in terms of impact to the disturbance of the pre-planned timeline and costs.

> ***System level user story US3.1****: As a manufacturing service requester/provider, I can use the impact prediction tool to quantify the impact of different types of unforeseen events in the production flow, so that I can make an informed mitigation decision*

Events can differ in type and can be either dependent on internal operations, such as quality issues, unscheduled maintenance tasks, and reduced capacity, while also on external events, such as unexpected market demand shortages, and delayed raw material arrivals. Either way, from the manufacturer's perspective, it can trigger additional costs during production, delayed shipment of products, additional discounts, or unexploited market opportunities. All these approaches will have a negative impact on the sustainability of the company, while also in the reliability to its customers.

> ***System level user story US3.1.1****: As a manufacturing service requester/provider, I can select from a list of unforeseen events that match my scenario and see the impact on my manufacturing goals*

It is expected that manufacturers will be able select from a list of different unforeseen events and identify the likelihood of realization, while also the impact on the preset company's goals.

> ***System level user story US3.1.2****: As a manufacturing service requester/provider, I can provide companies' data to train for my scenario*

Since this is a heavily case dependent scenario, there cannot be a universal model to identify supply chain disturbances based on totally pre-trained models, since the scenario for each manufacturing system may be drastically different. In that sense, it is crucial for the manufacturer to be able to register historical information from the logs selected from production, inventory, logistics, and sales departments, to allow the pre-trained system to adapt to the specific scenario.

> ***System level user story US3.1.3****: As a manufacturing service requester/provider, I can see the risk of cascading events caused by the initial unforeseen (e.g. the risk of an order to the customer to be delayed because the raw materials were delayed | comment managing to hedge that event internally means it is resilient)*

Considering that some events may be the trigger point for other (dependent) events to occur, it is important for the manufacturer to be able to see the list of cascading events and the potential implication to the system. For example, the delayed arrival of raw material from a supplier, may trigger low material availability on inventory, which can delay production by some days, if reaches extremely low volumes. The result, of course will be delayed shipment of products, yet being able to identify the cascading effect, and the reason of the delay is important enough to be able to troubleshoot the issue.

Once the impact of an unforeseen event can be estimated, the goal of the decision support tool is to provide immediate feedback on how to react to the event, based on the available data. The tool allows the user to do a high level trade-off analysis of which direction the reaction to the unforeseen event must go, i.e., looking for new suppliers (challenge 4), or adapting production (challenge 5).

> ***Epic user story US3.2**: As a manufacturing service requester/provider, I can get a back-of-the-envelope rough estimate of my manufacturing goal KPIs of temporary make/buy decisions on the spot by the decision support tool, without the need for asking other people for information, so that I can assess on the spot whether I will look for new suppliers or adapt production*

While general recommendations can be given, the decision support tool must be able to allow users to input specific what-if scenarios and the KPIs including of the manufacturing goals they want to evaluate in a trade-off analysis. This allows users to steer the analysis with specific assumptions, such as known suppliers or preferred outsourcing or in-house production of a given production step.

> ***User story US3.2.1**: As a manufacturing service requester, I can define what-if scenarios, in order to use the decision support tool with specific scenarios in mind*

In order to understand the actions that need to be undertaken, the product information in the product digital twin (PDT, see challenge 1) must be extended with production information in terms of the manufacturing goals. The added information is used in the trade-off analysis. This information can be added when building the product digital twin at design time, and when using the decision support tool, missing information can be added interactively.

> ***User story US3.2.2**: As a manufacturing service requester, I can extend my product digital twin with production knowledge in terms of my manufacturing goals, in order to obtain the back-of-the-envelope rough estimate by the decision support tool*

The decision support tool must use the proper trade-off comparison and visualization so that the manufacturing goals are optimized. The impact prediction tool can be used for this.

> ***User story US3.2.3**: As a manufacturing service requester/provider, I can use the decision support tool to handle the impact of the unforeseen events, so that the impact is minimized*

The main purpose of the decision support tool is to guide the user towards the supplier recommendation engine tool or to the dynamic planning and scheduling tool.

> ***User story US3.2.4**: As a manufacturing service requester, I can use the decision support tool to decide on whether to make changes to the supply chain or the internal production in case of an unforeseen event based on the predicted impact on my manufacturing goals*

4.5 Challenge 4: Enable companies to swiftly find suppliers and ensuring trust and reliability

In this scenario, a customer places an order for a product through the MaaS platform. A competitive bidding process is initiated among providers, where the best manufacturing provider is selected based on defined criteria such as cost, speed, carbon footprint, or other specific requirements.

During the order fulfilment phase, a disruption occurs in the supply chain—such as a delay in raw material delivery—making it impossible for the selected provider to meet the agreed-upon delivery time. The provider reports the issue back to the MaaS platform, triggering a contingency plan. The order is then reassigned to the second-best bidder based on the original evaluation criteria if they are signalling availability. Concurrently, an audit tool calculates the appropriate penalty for the first provider due to non-completion, ensuring accountability and maintaining service standards.

> ***System level user story US4****: As a manufacturing service requester, I can quickly find potential manufacturing service providers for my service request, so I can promptly react to medium-term unforeseen events.*

When choosing among the potential service providers, who provide similar services, the requester benefits from using some aggregated metric, which describes the performance of each provider. This helps the requester to make informed decisions and improves the level of trust in the network.

> ***Epic user story US4.1****: As a manufacturing service requester, I can use the supplier audit tool get a performance score about the potential manufacturing service providers for my service provided by the network, so I am informed when choosing manufacturing service providers.*

It is often difficult to manufactures to assess if they can produce some product or proved some manufacturing service. Currently, it is done manually by the experienced engineers who know the manufacturing processes and the available machines. Nevertheless, it consumes much time and may involve many errors. This is especially the case with SMEs as they may not have enough resources to keep track of all the manufacturing capabilities available to them. The MaaS network participants will benefit from using the audit tool that automatically evaluates manufacture's capabilities based on the production history and various technical documentation.

> ***User story US4.1.1****: As a manufacturing service provider, I can use the audit tool during my onboarding to the MaaS to have my service validated, so that I am confident that my manufacturing capabilities can ensure the provided service.*

The service requesters rely on the audit tool and are confident that the services advertised by the providers actually correspond to the manufacturing capabilities of the providers. This improves trust in the MaaS network.

> ***User story US4.1.2****: As a manufacturing service requester, I can use the supplier audit tool to automatically validate offers of manufacturing service providers, so that I can trust manufacturing service providers of the network.*

The audit tool will not only access the MaaS network participants manufacturing services but also rank them according to their history records in the system. This ensures trustworthiness from both the requesters' and suppliers' side.

> ***User story US4.1.3****: As a manufacturing service provider/requester I can use the ranking functionality of the audit tool, so I can better evaluate potential contractors and make informed decisions.*

In order to be able to promptly react to medium term disruptions manufactures can try to find the alternative manufacturing services in the MaaS network. Here, all the service relevant information and constraints must be considered. As the number of alternatives grows it will be impossible for a human to do the search manually. The recommendation engine will utilize the information from the standard services' models to match the required and the provided services. As the result, the list of the potential manufacturing services alternatives together with the matching score will be provided.

> ***Epic user story US4.2****: As a manufacturing service requester, I can use a recommendation engine tool to quickly find potential manufacturing service providers for my service request, taking into account all the relevant information, so I can promptly react to medium-term unforeseen events.*

As the change of one supplier can trigger a ripple effect across the supply chain, the recommendation engine must take this into account and generate the chains of possibilities.

> ***User story US4.2.1****: As a manufacturing service requester, I can use a recommendation engine tool that generates supply chain alternatives and provides recommendations about suitable manufacturing service providers, so I can make informed decisions.*

By using the matching algorithms and automatic negotiation protocols the recommendation engine can negotiate the terms and conditions with the potential manufacturing service provider automatically and afterwards provide the results to the user.

> ***User story US4.2.2****: As a manufacturing service requester, I can delegate the negotiation task with the potential manufacturing service providers to a recommendation engine tool, so I can focus on more urgent and important tasks and be more efficient.*

The make the informed decisions the service requester must get all the relevant information about the manufacturing service.

> ***User story US4.2.3****: As a manufacturing service requester, I can use a recommendation engine tool to get all the relevant information about the service, such as CO2 footprint, environmental and health impact, so I can choose only sustainable manufacturing service providers.*

To avoid ambiguities and misunderstandings, the information provided by the recommendation engine must comply with the common information model and use the domain specific vocabulary.

> ***User story US4.2.4****: As a manufacturing service requester/provider's production manager, I can understand the suggestions provided by the recommendation engine tool through the common information model.*

4.6 Challenge 5: Enable companies to swiftly create quotes and adapting production

When a new inquiry is received, the system automatically retrieves the service provider's capability data and compares it with the requirements specified in the inquiry. If a match is found, the system uses the matched data to generate an accurate quote, thereby streamlining the quotation process.

> ***System level user story US5****: As a production manager, I can optimize or adapt production, so that the impact of an unforeseen event is mitigated.*

> ***Epic user story US5.1****: As a manufacturing service provider, I can use the capability matching tool and trust that the service provided by me is automatically checked and matches the request, so that I can decide whether I can fulfil the contract.*

> ***User story US5.1.1: Automated Matching for Quotation Accuracy***

As a manufacturing service provider, I want the capability matching tool to automatically compare my service capabilities with the contract requirements, so that I can quickly determine if I can meet the specifications and generate an accurate quote accordingly.

As part of the quoting process, the system checks the provider's past performance records stored in a database. It assesses the reliability and quality of previous services rendered that match current request criteria. Based on this verification, a trust score is updated or confirmed, ensuring the client receives a reliable service proposal.When a new inquiry is received, the system automatically retrieves the service provider's capability data and compares it with the requirements specified in the inquiry. If a match is found, the system uses the matched data to generate an accurate quote, thereby streamlining the quotation process.

User Story US5.1.2: Real-Time Trust Verification

As a manufacturing service provider, I want the system to perform a real-time verification of my service provision capabilities against past performance data, so that the trustworthiness of my services is confirmed, ensuring that I can fulfil new contracts effectively.

The capability matching tool regularly syncs with the production system to fetch the latest updates on machine status, material availability, and personnel schedules. These updates are then reflected in the provider's capability profile on the platform, ensuring that any quotes generated are based on the most current production reality.As part of the quoting process, the system checks the provider's past performance records stored in a database. It assesses the reliability and quality of previous services rendered that match current request criteria. Based on this verification, a trust score is updated or confirmed, ensuring the client receives a reliable service proposal.

User Story US5.1.3: Seamless Integration with Production Systems

As a manufacturing service provider, I want the capability matching tool to integrate seamlessly with our existing production systems, so that any adjustments to production capabilities or schedules are automatically updated in my service offerings.

Upon detecting a disruption in the supply chain (e.g., a delay in material delivery), the system immediately evaluates the impact on ongoing and future production schedules. It then suggests feasible alternatives or adjustments, such as alternate material sources or schedule reshuffling, which the production manager can approve to maintain operational continuity.The capability matching tool regularly syncs with the production system to fetch the latest updates on machine status, material availability, and personnel schedules. These updates are then reflected in the provider's capability profile on the platform, ensuring that any quotes generated are based on the most current production reality.

User Story US5.1.4: Dynamic Response to Supply Chain Disruptions

As a production manager, I want the system to alert me and suggest alternatives when there are disruptions in the supply chain that affect my production capabilities, so that I can make swift adjustments to production plans or sourcing strategies to mitigate impacts on contract fulfilment.

Whenever new machinery is installed or existing machines are upgraded, the production planner updates the system with these changes. The system then automatically revises the capability profiles, ensuring that any future capability matching for contracts considers these enhancements, thus keeping the data used for client proposals up-to-date.Upon detecting a disruption in the supply chain (e.g., a delay in material delivery), the system immediately evaluates the impact on ongoing and future production schedules. It then suggests feasible alternatives or adjustments, such as alternate material sources or schedule reshuffling, which the production manager can approve to maintain operational continuity.

User Story US5.1.5: Proactive Capability Updating

As a production planner, I want to have the ability to update our capability profiles in as new equipment is added or existing capabilities are enhanced, so that the capability matching tool always has the most current data, increasing our responsiveness to contract opportunities.

Whenever new machinery is installed or existing machines are upgraded, the production planner updates the system with these changes. The system then automatically revises the capability profiles, ensuring that any future capability matching for contracts considers these enhancements, thus keeping the data used for client proposals up-to-date. In the context of disruptive events, it is necessary to react on current changes in order to avoid or at least minimize a loss of throughput. Similarly, the handling of generated offers affects the production schedule in the same way and needs to be handled. For this reason, a planning and scheduling procedure adapts the current plans to the upcoming changes.

Epic user story US5.2*: As a production manager, I can use the dynamic planning and scheduling tool, so I can mitigate the impacts of the disruptive events or swiftly generate offers to the incoming requests.*

After receiving a specific order, it has to be checked how the order could be fulfilled. Considering different constraints for the already planned production, there might be different options which are possible and can be offered.

User story US5.2.1*: As a manufacturing service provider's production manager, I can find all possible production plans for a specific order, so that I can make a timely offer for a manufacturing service requester.*

Considering the case that an upcoming event is confirmed and has to be scheduled, the planning tool generates an adapted production plan that handles the required changes. The resulting plan is determined according to the optimal handling of the required KPI's.

User story US5.2.2*: As a production manager, I can plan and schedule production based on data of the upstream supply chain, so that I can easily change production plans.*

Minimizing the expenditure of changing or equipping the production line is an important factor in reducing downtime. For this reason, it is necessary to automate this process using software and hardware with rows of code.

Epic user story US5.3*: As a manufacturing service provider's shift leader, I can use the dynamic execution tool deploy a new production plan, so that I can implement the mitigation action.*

By changing the tool loaded in the magazine and changing the trajectory, it is possible to change the execution with just a few parameters if the services provided are encapsulated and parametrizable.

User story US5.3.1*: As a manufacturing service provider`s shift leader, I can change the execution just by changing some parameters on the execution.*

To respond more quickly to unforeseen events, it is possible to send the new production plan directly from the network to the production lines in the factory and, depending on the event, start the setting-up for production.

> ***User story US5.3.2****: As a manufacturing service provider`s shift leader, I can send the production plan directly to the machine and worker.*

The service provider receives a forecast of production for the next time to agree or not the new production plan.

> ***User story US5.3.3****: As a manufacturing service provider`s shift leader, I can see the reaction of the production line before the new execution starts.*

5 Functional and Technical Requirements

The use of the imperative verbs such as shall, must, should in the requirements engineering is still under debate. The excessive use of the imperative verbs can lead to ambiguity. There is a consensus that the verb SHALL is used for the requirements that are mandatory and contractor binding. The other verbs do not convey the mandatory requirements, e.g., WILL can be used to indicate statement of fact and SHOULD – to indicate a goal.

In our requirements engineering task we are using only SHALL-imperative for the requirement formulation. We explicitly use the priority property to show if a requirement is mandatory or optional.

5.1 Data models and data exchange infrastructure

5.1.1 Service, capability and skill modelling

To enable the development of tools for the RAASCEMAN system, it is essential to collect and represent all information about the services, capabilities and skills of manufacturing service providers and requesters in a common way that is understandable to each participant. It is also necessary to use standard dictionaries, specifications and submodels to represent the machine, product and factories and to show interoperability between all participants.

> *REQ 1.1: The service, capability and skill modelling shall be able to represent all necessary information to exchange the offers and quotes between a manufacturing service provider and a requester.*

To establish a match between suppliers and customers within the MaaS system, each participant must reveal its services and capabilities to receive a contract to manufacture the requested product.

> *REQ 1.1.1: The service, capability and skill modelling shall provide all manufacturing services and information from a manufacturing service provider/requester and their machine, production lines and to manufacture the requested part.*

To avoid a huge development/modelling effort for the manufacturing service provider/requester, it is useful to use standard specifications and sub-models for the AAS/digital representation. If they have already implemented their own AAS/digital representation, it will only take a small adjustment to be part of this MaaS system.

> *REQ 1.1.1.1: The service, capability and skill modelling shall include standard specification and submodels for the AAS/digital representation of the machine, production lines and requested product.*

To match the different languages or descriptions of processing services between all participants, it will help to use a standard dictionary to describe their services. A standardized description will also make it possible to ensure the functionality of the tools being developed for our RAASCEMAN system.

> *REQ 1.1.1.2: The service, capability and skill modelling shall include a standard dictionary like ECLASS and IEC 61360 to have a common understanding of the provided/requested services and capabilities.*

When the requirements for manufacturing parts or machines and production lines in the factory are renewed or expanded, the supplier or requester must be able to change their published services to match the hardware in the factory or the product ordered.

REQ 1.1.1.3: The service, capability and skill modelling shall be editable by the manufacturing service provider/requester to adapt/add value to the services they provide/request.

To react to new regulations or to improve the exchange of data between the participants in the MaaS system, it must be possible for a consortium to extend and publish the actual data models and sub-models of products, machines and production lines.

REQ 1.1.1.4: The service, capability and skill modelling shall be extensible by a consortium to add new submodels required to exchange information between two participants.

Displaying the complex representation of services from the machine, production lines and requested parts in a GUI gives the users of the MaaS system a better overview of the services provided and requested and allows the manufacturing service provider/requester to edit/add their services.

REQ 1.1.1.5: The service, capability and skill modelling can have GUI to visualize the noted machines, production lines, requested parts, services and capabilities from the user of the MaaS.

To provide an update on the production progress of a part, it is useful to have a secure connection to the part's product status in the manufacturing service provider's factory. To follow the production status and to see possible complications of an unforeseen event.

REQ 1.1.1.6: The service, capability and skill modelling shall have a secure connection via the data from the machines and production lines to the MaaS platform to provide an update on the production of the requested part.

Enables communication between participants in the MaaS system to create quotes, request parts and receive updates on production progress.

REQ 1.1.1.7: The service, capability and skill modelling shall use a common language, such as the I4.0 language, which describes the vocabulary, message structure and interaction protocols.

To create data sovereignty over critical production information, it can be useful to run the AAS/digital representation of machines, factories and products locally in each environment and send information to the MaaS when it is needed.

REQ 1.1.1.8: The service, capability and skill modelling can provide the AAS/Digital Representation locally in each factory.

For different stakeholders within the MaaS system, it is necessary to provide different levels of access to the data model to modify information.

REQ 1.1.1.9: The service, capability and skill modelling shall provide different access levels to connect and edit the AAS/Digital representation.

5.1.2 Product digital twin

To provide all relevant information in a common and efficient way by using a product digital twin (instance and aggregated level), so that the information related to the manufacturing of the product (including the several middle steps) is available to different stakeholders as needed.

REQ 1.2: The PDT shall allow the service requester/provider participating in the MAAS network to describe information related to their product, so that the product can be used easily over its full lifecycle.

To view and edit information related to capabilities and skills needed for the manufacturing of each product.

REQ 1.2.1: The PDT shall include the capability, service, and skill (CSS) model of the product that encompasses the standardized AAS models and submodels.

To provide details about measurable goals and other relevant features.

REQ 1.2.2: The PDT shall include editable models that can store values related to relevant features like process duration, cost and carbon footprint, to name a few, based on the need of the product.

To specify details related to the skills needed for developing a product in terms of the CSS model, so as to match it with the services in the network.

REQ 1.2.3: The PDT shall include editable models to store information about skills and values related to relevant features like process duration, cost and carbon footprint, to name a few, based on the need of the product.

To provide the product specifications in the standardized AAS models and submodels by using ECLASS ID.

REQ 1.2.4: The PDT shall have a GUI or editable models to specify products based on standards such as ECLASS ID.

To specify and aggregate relevant product information like BoM, BoP, quality information, etc., with the CSS model

REQ 1.2.5: The PDT shall provide mechanisms to provide an aggregated view of different information such as BoM, BoP, quality control, to name a few.

To include information on a product instance level (digital product passport (DPP)), so that progress on manufacturing can be tracked as requested.

REQ 1.2.6: The PDT shall include editable models to store information about the different steps used in the manufacturing of a product, in order to create a holistic digital product passport (DPP).

To include information at an aggregate level, which includes a collection of functional Digital Twins (system and process models along with related simulations) that will be included into the DPP, which will be used during the entire lifecycle of a product.

REQ 1.2.7: The PDT shall include editable models to aggregate information about the different digital twins (such as system, process models) to track the entire lifecycle of a product.

5.1.3 Information infrastructure

A well-defined API should support the generation and management of Asset Administration Shells (AAS).

REQ2.1 Support the creation and manipulation of AASs. (API)

To ensure real-time communication between field level devices (machines, sensors etc.) and their digital representatives (AAS); standardized communication protocols should be supported.

REQ2.1.1 Support standardized protocols (OPCUA, MQTT, REST etc.) for linking shopfloor data with corresponding data models (AAS).

The system should be able to store, manage and retrieve historical IoT data. These data are crucial for various operations such as maintenance and process optimization.

REQ2.1.2 Provision of historical data (IoT data).

5.1.4 Data platform extensions

The system should allow network participants to determine sharing policies, defining who accesses specific information.

REQ2.2 Provision of the ability to define data sharing policy.

The system should support standardized interfaces to ensure secure data exchange between different systems/companies.

REQ2.2.1 Provision of standardized interfaces for sharing and consuming information.

5.2 Supply Chain Level Support Tools

5.2.1 Tool for impact prediction of disruptive events

For manufacturers the main objective is to be able to analyse and assess potential risks and costs for their industry. As such, the primary business requirement is the following.

REQ3.1 Impact Prediction Tool must be able to assess the risk of different supply chain disturbances and predict associated impact to the business performance.

This was broken down to different functional requirements, with the first being to provide the ability to integrate different information data sources, conveying information about production and supply chain status.

REQ3.1.1 Impact prediction tool must be adaptable to different business cases and integrate information regarding its current status.

In terms of technical requirements, there need to be ensured that,

REQ3.1.1.1 The software provides connectivity with industrial data dynamically and identify the latest status and events on runtime.

As long as the required connection have been established and information have been received, the tool should,

REQ3.2.1 Impact prediction tool must calculate and display the likelihood of specific events and an estimation of its impact in the company's KPIs.

In terms of technical requirements, this specifies the need to allow adaptability and retainability of the models to a specific scenario, and quick response to the user's requests for risk assessment and impact prediction,

REQ3.2.1.1 There should be a specific list of event types upon which the model must be able to be re-trained based on a company's historical data.

REQ3.2.1.2 The tool must provide the ability to select among different events and display the probability of the event happening upon a specific horizon, along with the cost/benefit for the company.

5.2.2 Decision support Tool for companies in a dynamic MaaS network

The goal of the decision support tool is to use manufacturing goal KPIs (cost, lead time, etc.) to provide decision support for several scenarios.

REQ3.2 The decision support tool shall be able to present decision support information in terms of manufacturing goals.

The tool is meant to provide guidance on-the-spot for fast decision making.

REQNF3.2.1 The decision support tool must provide feedback upon requests within 10 seconds.

The decision support is based on available data from MaaS network (catalog of services with their product capacity), internal production system (ERP and MES systems) and product digital twin (product and process states, and manufacturing needs). This means that the tool is connected to these systems and is able to extract the right information. Both the current state as well as historical data must be accessible.

REQ3.2.1 The decision support tool shall have access to historical and state data for its analysis.

REQ3.2.1.1 The decision support tool shall incorporate historical data from the MaaS network for its analysis.

REQ3.2.1.2 The decision support tool shall be able to use data describing the current state of the MaaS network.

The current state of the internal production system must be known to understand high level possibilities, e.g., are needed skills available in the production system? This means that high level information about the production system must be known, such as skills and services, and availabilities and capacities.

REQ3.2.1.3 The decision support tool shall be able to use data describing the current state of the internal production system.

Similarly, the PDT data must be accessible to take product needs into consideration for the decision support tool.

REQ3.2.1.4 The decision support tool shall be able to use product digital twin data with embedded manufacturing goal metrics.

The decision support tool allows trade-offs between different possible scenarios by using the impact prediction tool. The right "what-if" scenario must be given as input to the impact prediction tool to understand the impact on production goals, including uncertainty.

REQ3.2.2 The decision support tool shall be able to use the impact prediction tool with what-if scenarios.

REQ3.2.2.1 The decision support tool shall be able to send a scenario in the input format of the impact prediction tool.

REQ3.2.2.2 The decision support tool shall be integrated with the output format of the impact prediction tool.

The decision support tool must visualize comparisons between the two major options to handle the consequences of an unforeseen event, namely finding a new supplier or changing production, i.e., the user needs to make a "temporary make-or-buy decision". This will offer decision support for the user to understand what tools he must use to find a solution for handling the unforeseen event.

REQ3.2.3 The decision support tool shall visualize a trade-off between finding a new supplier and changing production.

REQ3.2.3.1 The decision support tool shall include a visualization of the temporary make-or-buy analysis with a comparison of the manufacturing goals.

REQ3.2.3.2 The decision support tool shall include an explicit visualization of uncertainty on every estimated manufacturing goal metric.

The user must be able to incorporate their manufacturing goals (e.g., cost, lead time, etc.) to drive the trade-off analysis and visualize the results.

REQ3.2.4 The decision support tool shall include a user interface to edit manufacturing goal metrics and events.

Uncertainty needs to be explicit in the decision making. Therefore, the user needs to be able to specify their assumptions on certain manufacturing goal metrics (e.g., cost, lead time, etc.) or events (e.g., no on-time delivery of supplier), as an addition of what can be determined from historical data.

REQ3.2.4.1 The editor shall allow users to define uncertainty for a metric in terms of a probability distribution.

REQ3.2.4.2 The editor shall allow users to define uncertainty for an event in terms of a probability.

5.2.3 Audit Tool for trustworthiness and reliability in a dynamic MaaS networks

The primary purpose of the audit tool is to support and increase the level of trust in the MaaS network by automatically validating the correspondence of a manufacturing service to the production capabilities and capacities. This functionality is beneficial for the service provider, as well as for the service requester.

For the service provider it helps with the service onboarding to the network.

REQ4.1.1.1 The audit tool shall during the manufacturing service onboarding to the MaaS validate this service if it corresponds to the manufacturer's production capabilities.

For the service requester it helps to make the informed decisions and support automatic service negotiation.

REQ4.1.1.2 The audit tool shall automatically validate if the offered service can be provided by the manufacturing service provider.

The level of trust can be represented based on some aggregated metrics or a performance score, which assess not only the production capabilities, but also the historical data about the participant's activity in the network.

REQ4.1.1.3 The audit tool shall provide a performance score about the potential manufacturing service.

5.2.4 Recommendation engine for dynamic supply chain generation

The primary purpose of the recommendation engine is to search the MaaS network for the manufacturing services required by the manufacturer according to the product specifications, goals and constrains. It automatically compares requested and provides services on the network using capability matching technique and provides a list of alternatives.

REQ4.1.2.1 The recommendation engine shall generate the supply chain alternatives for the requested manufacturing service.

The process of searching for the required services normally involves some negotiations, which the recommendation engine will do automatically.

REQ4.1.2.2 The recommendation engine shall be able to automatically negotiate with the potential manufacturing service providers.

The similar services shall be ranked according to the requester's criteria.

REQ4.1.2.3 The recommendation engine shall rank the potential manufacturing service providers based on their production capabilities and the requester's goals.

To support the circular and responsible manufacturing, the information about the service shall consist of all the necessary or required by the EU laws data.

REQ4.1.2.4 The recommendation engine shall provide all the relevant information about the offered service, such as CO_2 footprint, environmental and health impact.

It is important to provide the information in the standard form in compliance with the common information model and using vocabulary that is common in the relevant manufacturing domain.

REQ4.1.2.5 The recommendation engine shall provide the information about the manufacturing services in compliance with the common information model.

Duplication of services.	M	The services in the network must duplicate each other to enable the choice.
The UC product must provide variability.	S	The product of the use-case should provide variability to justify the need for new services.

5.3 Factory Level Support Tools

5.3.1 Tool for matching procedure and capability matching

The Tool for Matching Procedure and Capability Matching will be designed to align manufacturing resource capabilities with production requirements in dynamic MaaS networks. It ensures the identification and allocation of the most suitable resources to meet technical, operational, and economic needs. By leveraging GraphDB for structured data representation, LLMs for semantic understanding, and RAG for enhanced data retrieval and decision-making, the tool will facilitate interoperability across diverse systems. This enables precise, real-time resource-task matching, even in rapidly changing manufacturing environments.

> *REQ5.1: The tool shall employ a semantic framework that integrates with the broader RAASCEMAN information model, supporting standards such as Asset Administration Shells (AAS) and OPC-UA and the use of standard dictionaries for consistent capability descriptions.*

MaaS networks involve diverse systems, machines, and tools. Using a standardized semantic framework ensures compatibility and seamless communication between components. Standards like AAS and OPC-UA, combined with dictionaries such as ECLASS and IEC 61360, provide a uniform language for describing capabilities, reducing misunderstandings and errors in resource-task alignment. A consistent framework makes it easier to integrate new resources, systems, or partners into the RAASCEMAN network without reworking the semantic foundation.

> *REQ5.2: The tool shall represent all relevant service, capability, and skill data of resources in a GraphDB-based structure. It shall enable real-time querying based on capability requirements specified by manufacturing service requesters.*

Manufacturing involves complex relationships between resources, capabilities, and tasks. GraphDB efficiently organizes these relationships, enabling quick and accurate retrieval. Dynamic MaaS environments require tools that can respond to changing needs or disruptions immediately. Real-time querying ensures timely updates and decisions. Storing data in a GraphDB allows for fast search operations, crucial for scenarios where decisions must be made rapidly, such as rerouting resources due to unexpected machine downtime.

REQ5.3: The tool shall support manufacturing systems (MES, ERP) to reflect changes in machine states, tool availability, and personnel scheduling.

Changes in machine states (e.g., downtime, maintenance), tool availability, or personnel schedules directly impact production. Integrating with MES and ERP systems ensures the tool reflects the latest data. By staying synchronized with real-world conditions, the tool prevents mismatches between planned capabilities and actual resource availability. Up-to-date information enhances the accuracy of resource-task matching and allows for proactive decision-making, such as rescheduling tasks or reallocating resources.

REQ5.4: The tool shall integrate with dynamic planning and scheduling systems from sections 5.3.2 and 5.3.3. It will support the task planning and execution tools by exporting capability-matching results for operational readiness.

Seamless integration with planning (5.3.2) and execution (5.3.3) tools ensures that the results of capability matching are effectively used for task scheduling and their implementation in production. By connecting the matching tool to other systems, the RAASCEMAN network avoids isolated operations and ensures cohesive workflows from planning to execution. Exporting results for operational readiness ensures that capability matches are not just theoretical but can be directly implemented in real-world production.

REQ5.5: The user interface shall accept input in natural language, processed by an LLM for compatibility and ease of use. It will provide actionable recommendations for resource-task matching and highlight resource unavailability.

A natural language interface ensures accessibility for all stakeholders even if they are not experts in production planning or management. LLMs provide semantic understanding of user inputs, ensuring accurate interpretation of task requirements and suggesting the best matches. Highlighting unavailable resources ensures users can make informed decisions, such as considering alternative resources or adjusting task priorities. Simplifying interactions reduces the time spent on configuring and querying the system, speeding up the decision-making process.

5.3.2 Tool for dynamic planning & scheduling

The need of dynamic planning and scheduling in constantly changing environments is substantial. Every time a new event occurs, the tool triggers the planning algorithm to handle the new situation and creates an adapted plan.

REQ5.2: The tool for dynamic planning and scheduling shall be triggered if unforeseen or planned events occur to adapt the current production plan.

To create a new production plan, the tool needs different information about the current and the expected state of the production process. The tool has to take care about the ongoing processes in the factory and about the information and orders that come from outside. Only with all necessary information available, the tool will be able to produce informed production plans.

REQ 5.2.1: The tool for dynamic planning and scheduling shall have an interface to communicate to intra- and inter-factory components to provide meaningful production plans.

In dynamic environments, already calculated plans can become obsolete very quickly. For this reason, it is necessary to have different options that could be applied to the production line. Furthermore, the resulting plans should only have little effects on the current process such that the application of a plan is very likely.

REQ 5.2.1.1: The tool for dynamic planning and scheduling shall provide different executable plans that can be easily applied in the production procedures.

The tool should provide information about the current progress and already calculated plans. This is necessary to estimate when new plans will be available, in particular, if several events occur.

REQ 5.2.1.2: The tool for dynamic planning and scheduling shall notify connected services about the current progress of the planning and scheduling procedure and already available results.

The tool should provide the results within several minutes which is acceptable in industrial context. This ensures enough calculation time to find a suitable solution in a reasonable amount of time and enables faster recalculation to upcoming changes and events.

> *REQ 5.2.1.3: The tool for dynamic planning and scheduling shall be able to provide adapted production plans in real-time such that it can be used dynamically.*

5.3.3 Dynamic execution of tasks on the shopfloor

The manufacturing service provider should be able to react to unforeseen events in a few steps. For this reason, a tool should be implemented to assist the supplier in preparing the new executions on their production lines and machines. This tool displays the prepared execution, and the service provider can decide to start the execution of the order.

> *REQ 5.3: The dynamic execution of tasks on the shopfloor shall be able to react to unforeseen events and change the production equipment on the shopfloor in a short time to execute a new process.*

To enable the execution of a new order from the MaaS system, the tool must have a software interface to the shopfloor to send the production plan with a few production parameters to prepare the production lines and the machine for the execution.

> *REQ 5.3.1: The dynamic execution of tasks on the shopfloor shall have a software interface to change the production with a small number of parameters.*

The interface of the tool must have flexible parameters to adapt to every capability of the production lines and machines of the factory, in preparing the execution that will be started by the manufacturing service provider.

> *REQ 5.3.1.1: The dynamic execution of tasks on the shopfloor shall have a parameterizable software interface to prepare the execution of production changes for production lines and machines.*

From the tool, the manufacturing service provider must be able to trigger production with the prepared parameters to keep the reaction time of the machine and production lines to unforeseen events as low as possible.

> *REQ 5.3.1.2: The dynamic execution of tasks on the shopfloor shall be able to trigger the execution of production by the manufacturing service provider.*

The tool displays the impact or action required to trigger the new order in the production lines and machines.

> *REQ 5.3.1.3: The dynamic execution of tasks on the shopfloor shall provide information on the duration and scope of production for the manufacturing service provider.*

The manufacturing service provider must be notified when the tool has prepared a new parameter set to trigger the new order on the production lines and machines.

> *REQ 5.3.1.4: The dynamic execution of tasks on the shopfloor shall notify the manufacturing service provider that the production is ready to produce the new order.*

6 Conclusion

We discussed the high level requirements in this deliverable in a structured way with a well-defined methodology that includes the specification of glossaries, use cases with templates and BPMN, user stories, and user requirements, developed through workshops. Starting from five challenges defined in the proposal, we elicited specific requirements from the point of view of each individual pilot, resulting in descriptions of specific context, stakeholders, unforeseen events, goals and acceptance criteria. In a next step, we defined the interaction and requirements of the RAASCEMAN system from the point of view of the system and its general users. We set up collaborative documents for tracking and extending requirements throughout the project. The result of this deliverable is that the needs of the RAASCEMAN system are clarified and aligned with the consortium. This document serves as input for Task 1.3 (software system specification), and the technical tasks of WP 2, 3, 4, 5.