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RAASCEMAN

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

Grant Agreement No. 101138782

Deliverable 1.2

Demonstrator descriptions and evaluation method

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Executive Summary

The RAASCEMAN project (Resilient and Adaptive Supply Chains for Capability-based Manufacturing as a Service Networks) aims to transform traditional manufacturing by introducing an innovative capability-based Manufacturing-as-a-Service (MaaS) platform. This deliverable (D1.2) is a supplementary document to D1.1, providing a more detailed description of the use cases and demonstrators. While D1.1 outlined the high-level objectives and challenges of the RAASCEMAN project, D1.2 expands on these concepts by presenting the specific implementation details of the demonstrators. Additionally, this document defines the communication interfaces and partially describes the data models, which serve as a foundation for the development of the RAASCEMAN software platform. This overarching software platform will integrate RAASCEMAN results and enable their evaluation within the use cases, ensuring a seamless and practical transition from conceptual design to real-world application.

The use cases described in this deliverable serve as the foundation for evaluating the MaaS concepts developed in the project. The requirements for the common software platform are directly derived from these use cases, ensuring that the system is designed and implemented to address real-world manufacturing challenges. The evaluation of these demonstrators will validate the feasibility, efficiency, and interoperability of the RAASCEMAN platform before full-scale deployment.

The first demonstrator focuses on the Automotive Use Case, implemented by Continental, where the goal is to enhance production efficiency by minimizing manual interventions and optimizing production control systems. Through advanced automation and data-driven decision-making, the use case aims to reduce changeover times to two hours and improve Overall Equipment Effectiveness (OEE). The evaluation criteria include measuring daily deviations between planned and actual production output, with the objective of limiting discrepancies to fewer than 150 units per day. Additionally, the integration of the RAASCEMAN platform is expected to enhance supply chain reliability, ensuring that at least 95% of external orders are fulfilled on time. The system's seamless interoperability will be validated through the successful implementation of REST API interfaces, enabling real-time data communication between production lines and the MaaS network.

The second demonstrator, the Bike Production Use Case led by ASKA Bikes, presents a different yet complementary challenge. Unlike conventional e-bike production, which is heavily reliant on suppliers in China and Taiwan, ASKA Bikes prioritizes localized European manufacturing to create a more sustainable and flexible production ecosystem. The focus of this use case is on optimizing component manufacturing by reducing lead times, improving quality control, and enhancing supplier coordination. The evaluation framework includes key performance indicators such as reducing the lead time from supplier selection to prototype production to three months, lowering defect rates to one percent, and ensuring that at least 90% of orders are delivered on time. By leveraging digital process descriptions and automated quality control systems, this use case ensures more efficient and cost-effective supplier collaboration. Furthermore, the requirements for the RAASCEMAN software platform's supplier integration capabilities are motivated by the challenges identified in this use case.

The third demonstrator, involving Interconnected Pilot Lines from CTU, DFKI, RPTU, and FM, serves as a controlled testbed environment for evaluating the RAASCEMAN platform's capabilities in a multi-factory setting. These pilot lines integrate cyber-physical systems, automated decision-making, and digital twins, allowing for rigorous testing of interoperability and cross-factory collaboration. One of the primary goals is to achieve at least 90% compliance with a unified semantic model, ensuring that

all manufacturing nodes in the network communicate using standardized protocols such as OPC UA and MQTT. Additionally, the pilot lines aim to reduce human decision-making time in unexpected events by at least 25%, leveraging AI-driven planning and predictive analytics. The success of this demonstrator will be evaluated based on system robustness, with acceptance criteria including three consecutive stress-free integration tests and zero critical failures during interoperability assessments. These pilot lines also provide the necessary environment to test the real-time adaptability and connectivity of the RAASCEMAN software platform.

A key aspect of this deliverable is the definition of communication interfaces and data models, which serve as the technical backbone for integrating the RAASCEMAN results into the overarching software platform. These interfaces ensure that the developed MaaS concepts are seamlessly connected across different use cases and allow for interoperable, real-time data exchange between diverse manufacturing environments. By establishing a standardized approach to data flow and system interaction, this deliverable lays the groundwork for future scalability and expansion of the RAASCEMAN platform beyond the initial demonstrators.

The KPIs defined for each use case contribute directly to solving the challenges outlined in the RAASCEMAN project proposal. The automotive use case addresses the need for automated, efficient production control by integrating real-time planning and predictive maintenance. The bike production use case tackles supply chain flexibility and reliability, demonstrating how local supplier integration and optimized workflows can improve manufacturing resilience. The interconnected pilot lines contribute to semantic interoperability and real-time decision support, ensuring that the RAASCEMAN platform can function across diverse industrial environments. By systematically evaluating these KPIs, the project verifies that the developed MaaS platform meets the requirements for enhanced cross-factory communication, automated supplier selection, and adaptive production planning.

By implementing these demonstrators and validating their performance against rigorous evaluation standards, the RAASCEMAN project demonstrates how capability-based manufacturing can revolutionize modern supply chains. The MaaS platform enhances data-driven decision-making, facilitates adaptive production planning, and ensures seamless supply chain coordination. Through cross-site collaboration and real-time digital integration, the project establishes a blueprint for future-ready, resilient, and flexible manufacturing ecosystems. The insights and findings from these use cases will shape the development and refinement of the RAASCEMAN software platform, ensuring that it is tailored to meet the needs of real-world manufacturing environments while enabling next-generation intelligent and interconnected supply chains.

1 Introduction

1.1 Objectives

This deliverable aims at providing detailed description of three operational demonstrators provided by the partners in RAASCEMAN. The description contains a general structure of the demonstrators, with specific focus on protocols used and site-specific adaptations required. Based on the description, the SW architecture of the RAASCEMAN MaaS[1] system will be designed to be able to connect all demonstrators.

1.2 Evaluation and acceptance

The evaluation framework ensures that each demonstrator and use case meets its predefined objectives. It emphasizes quantitative and qualitative metrics for performance, focusing on improving supply chain resilience and adaptability.

Key Performance Indicators (KPIs) of each use case and pilot line are divided into measurable benchmarks to evaluate system improvements, including:

1. Automotive Use Case (Continental):
    - Metrics like production output, OEE prediction accuracy, supply chain reliability, and system integration success rates.
    - Example: Reducing daily deviations in planned vs. actual output to under 150 units.
2. Bike Production Use Case (ASKA Bikes):
    - Metrics for lead time, cost efficiency, defect rate, flexibility, and on-time delivery (OTD).
    - Example: Achieving a lead time of 3 months for first prototypes while maintaining a defect rate under 1%.
3. Interconnected Pilot Lines (DFKI, RPTU, FM, CTU):
    - Focuses on semantic compliance, communication protocol adoption, decision-making speed, and planned vs. actual production matching.
    - Example: Achieving 90% compliance with the semantic model across system components.

Evaluation Methods aim to validate system performance through:

- Real-time monitoring: Using MES and ERP systems to gather live data on production and supply chain activities.
- Simulation and digital twins: Testing scenarios in a controlled virtual environment before deploying them in real production.

[1] Manufacturing as a Service

- Operator feedback: Collecting insights on user experience and system usability for continuous improvement.
- Stress and integration tests: Verifying the robustness of communication protocols and system reliability under simulated stress conditions.

Acceptance Criteria

Specific thresholds are defined for evaluating success:

- Each KPI has target fulfillment percentages (e.g., achieving 95% or higher accuracy in predictions or integrations).
- Benchmarks for system robustness, like three consecutive stress-free integration tests or minimal downtime in production.
- Operator training and adoption rates, emphasizing knowledge transfer and system usability.

Cross-Demonstrator Insights highlight the importance of cross-demonstrator connection even if each use case and pilot line is evaluated individually. However, shared goals such as improved system communication, seamless integration, and adaptive decision-making are consistently emphasized. Additionally, results from one demonstrator inform enhancements in others, creating a cohesive improvement strategy.

2 Description of use cases

This section is a summary of the high-level needs of the system that define the high-level scope of the RAASCEMAN MaaS system, which is going to address the following high-level challenges.

1. Common semantic representation
2. Intra- and cross-factory communication based on standards and European values
3. Enabling human decision maker to react to unforeseen events with the support of automated tools
4. Enable companies to swiftly find suppliers and ensuring trust and reliability
5. Enable companies to swiftly create quotes and adapting production

The challenges are discussed in detail in D1.1. The use cases described here provide the basis where to evaluate if the challenges are solved with the means of RAASCEMAN results.

2.1 Automotive Use Case (Continental)

2.1.1 Use Case Description

The use case (UC) in Continental is about optimal production control with minimum manual intervention of the operators to changing the production plans. Moreover, the optimal production control is supposed to allow for **shortening the change-over times** down to 2 hours and thus **increase the overall equipment efficiency** (OEE). More details about the goals of this UC are provided in Deliverable 1.1 The production consists of 6 interconnected production lines as depicted in Figure 1, where display panels for car dashboards are produced. The panels consist of several parts produced at the individual production lines, which are assembled and tested at the final assembly line to obtain the **final product**.

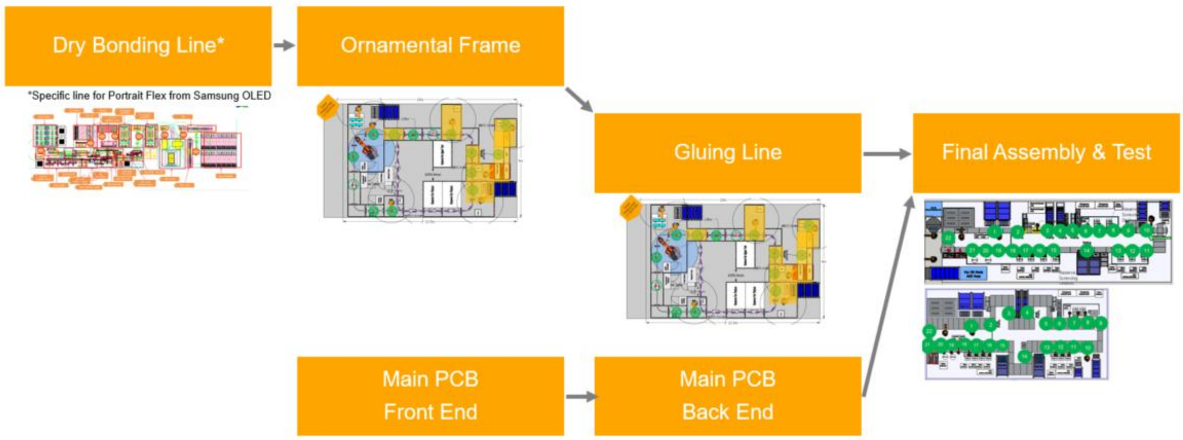


Figure 1: Production in the Continental Use Case

Figure 2 depicts the logical structure of the UC. The input data stem from the ERP (**Enterprise Resource Planning**) system and from the MES (**Manufacturing Execution System**). The ERP system contains high-level data necessary to produce the final products. These data relate to technological recipes such as BOM (Bill of Material) and routings (the way, which the individual pieces of material move in the production to merge to the final product). There is also data about material availability in the ERP system, may it be data about raw material, warehouse status or line material, i.e. material available at production lines. Finally, the ERP system contains information about production orders and call-offs, i.e. changes in the production orders.

The MES contains information about the work in progress, which is also used by the ERP system to the line material availability, history and current data about the equipment utilization (OEE). The MES also receives production orders.

A digital twin of the production is available, which allows checking production scenarios before they are executed in the real production.

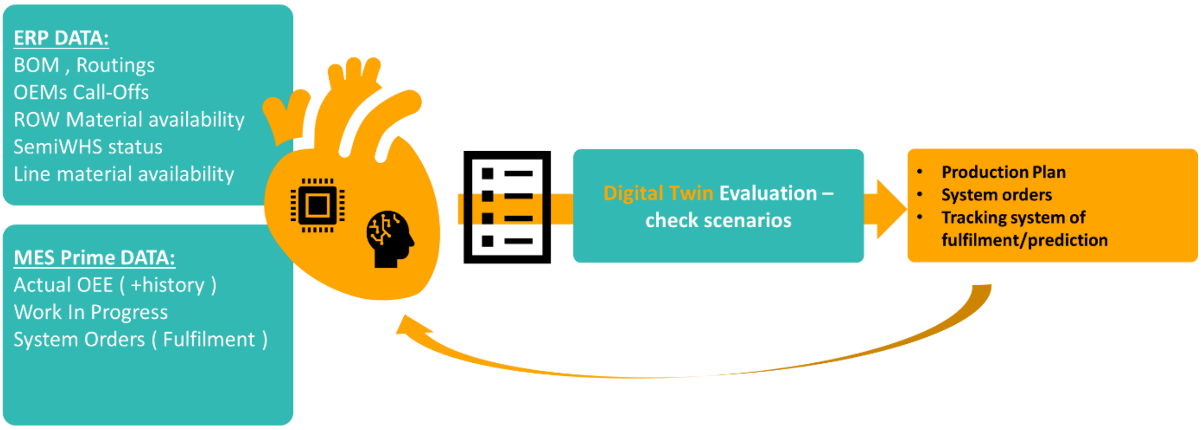


Figure 2: Logical structure of the Continental Use Case in the virtual mode

Figure 3 provides more details about the system architecture. The ERP system is part of group of systems denoted as Production/logistics planning, which symbolizes the fact the internal as well as external supply chain is handled, as well as the material and warehouse management.

Based on that, the production orders are issued towards MES, and the finished production is signalled back from MES to the ERP system. Figure 3 contains a block marked with X, which represents a virtual “switch” to route the data and command flow between the real production, virtual production, ERP system and the RAASCEMAN MaaS platform. The virtual production consists of the digital twin and the testing MES instance, which allows receiving commands and sending data back to the RAASCEMAN MaaS platform. The X “switch” also allows, however, to connect the RAASCEMAN MaaS platform to the real production to evaluate the RAASCEMAN results in a dry run of the production under controlled conditions.

The RAASCEMAN MaaS platform’s involvement in the production control is indicated by the green arrows to/from the X “switch” and from the ERP system. The latter means transport of data about the system orders in a form of a file export.

In such a way it is ensured that the reliable run of the real production is not harmed during experiments with production planning and production control. However, the architecture allows easy switching to real production (under controlled conditions), if the testing and evaluation of the RAASCEMAN results are successful.

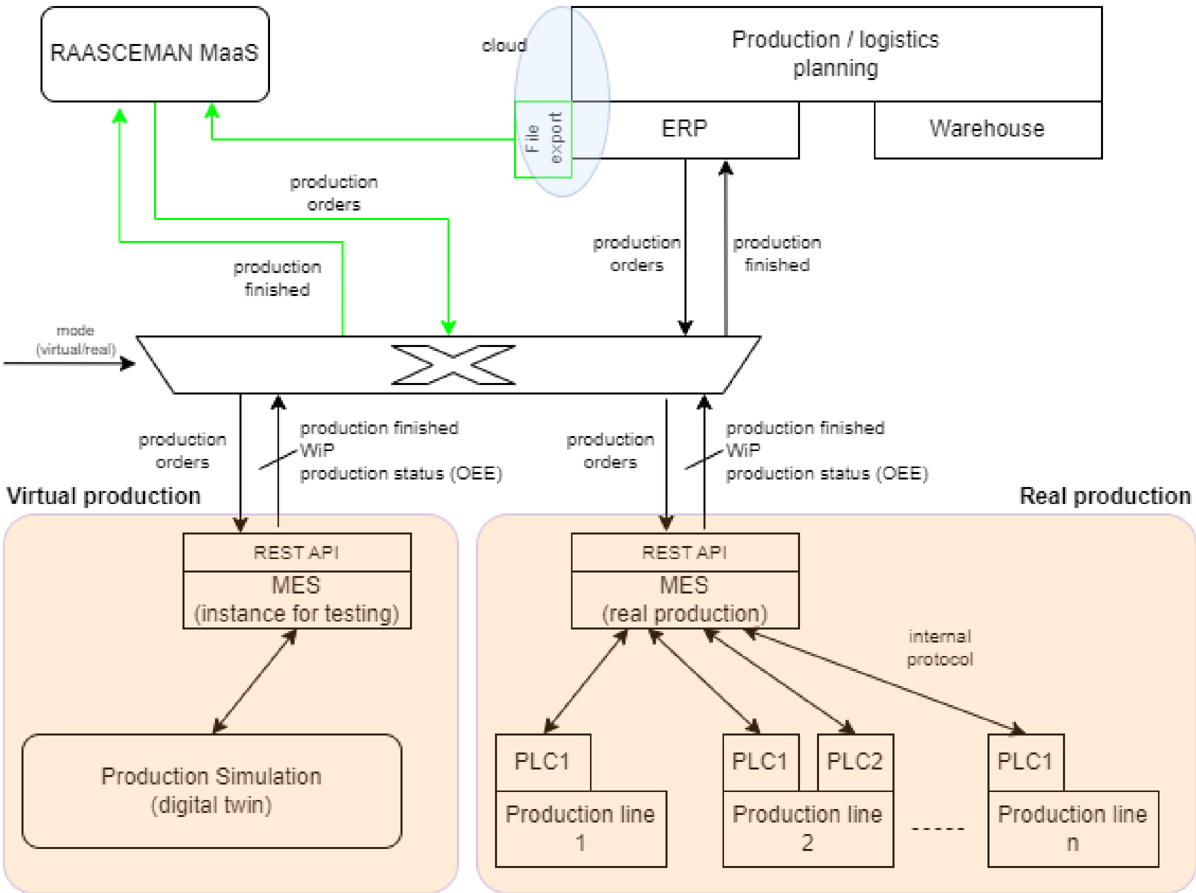


Figure 3: System architecture of the production in Continental Use Case

2.1.2 Use Case KPIs

	KPI	Fulfilment			KPI Description
		0%	**50%**	**100%**	
KPI-1	Plan vs. Output [pcs/day]	-500	150	0	Comparison between create plan and real output from production lines
KPI-2	OEE prediction [%]	50	20	5	After 6-month prediction of a OEE KPI, deviation between prediction and real OEE
KPI-3	External Orders fulfilment "JIT" [%]	80	95	100	Material availability from supplier/intercompany
KPI-4	Line Integration [%]	0	50	100	Line integrated in RAASCAMAN Planning (Project Audi Panorama)
KPI-5	SCM Planners Trained [%]	0	70	100	Knowledge level
KPI-6	Implement REST API interface towards the RAASCEMAN platform.	50%	80%	100%	Percentage of nodes in the RAASCEMAN MaaS network successfully communicating via standardized protocols.

2.1.3 Evaluation and Acceptance Criteria

	Evaluation	Acceptance Criteria	Challenge #
KPI-1	- Compare planned daily production quantities with actual output using MES and ERP logs. - Conduct weekly variance analysis to track discrepancies and identify root causes.	- The daily deviation between planned and actual output is reduced to less than +150 units. - The percentage of production days meeting planned output	5

	Evaluation	Acceptance Criteria	Challenge #
	- Perform dry runs with the RAASCEMAN platform to test plan adherence under controlled conditions.	exceeds 90% over a 3-month period.	
KPI-2	- Monitor and log real-time OEE metrics alongside predicted values over a 6-month period. - Calculate the deviation between predicted and actual OEE. - Validate the OEE prediction model through controlled experiments using the digital twin.	- The deviation between predicted and actual OEE does not exceed 5%. - The prediction model achieves 95% accuracy in at least three consecutive simulation tests.	3, 5
KPI-3	- Track on-time delivery performance for orders using ERP system. - Compare delivery timelines with planned schedules under the RAASCEMAN platform's enhanced supply chain visibility. - Conduct monthly reviews to evaluate performance and material availability.	- At least 95% of orders are fulfilled on time within a 3-month rolling window. - The on-time fulfilment rate reaches 100% for at least two consecutive months.	4, 5
KPI-4	- Test the integration of all production lines into the RAASCEMAN planning system through simulated and real scenarios. - Measure data flow consistency and latency during line integration tests. - Validate system functionality in planning, execution, and reporting tasks.	- 100% of production lines are integrated into the RAASCEMAN platform. - No critical system failures occur during three consecutive end-to-end integration tests.	2
KPI-5	- Monitor training attendance and completion rates using the training platform or logs. - Conduct pre- and post-training assessments to evaluate the knowledge gained by SCM planners. - Use follow-up surveys to measure planners' confidence and satisfaction with the training.	- At least 70% of SCM planners complete training modules and pass post-training assessments before the beginning of the rolling window. - 100% of SCM planners achieve certification and demonstrate proficiency in using the RAASCEMAN at the end of the rolling window. - 90% of trained planners report improved confidence in managing supply chain tasks in post-training surveys.	3, 5
KPI-6	- Conduct integration tests to verify communication compatibility using selected protocols. - Use message flow logging to ensure uninterrupted data exchange between the testbeds and the RAASCEMAN platform.	- There is a successful data exchange using standardized protocols. - No critical communication failures during three consecutive stress tests.	2

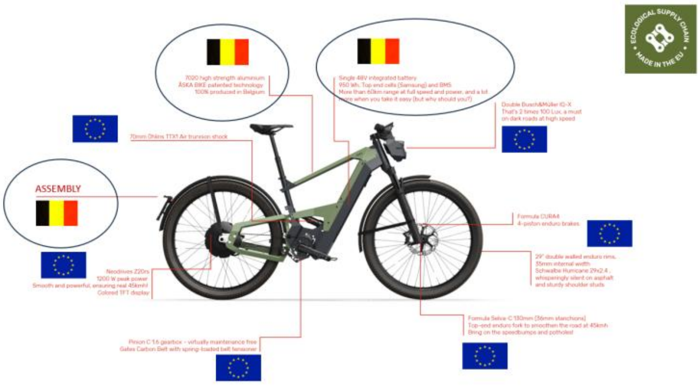
2.2 Bike Production Use Case (ASKA Bikes)

2.2.1 Use Cases Across the Lifecycle of Aska Bike

At ASKA, we are redefining the e-bike industry by focusing on durability, quality, and sustainability. Unlike traditional e-bike production, where up to 90% of the value chain lies in China and Taiwan, we take a local production approach. Our speed pedelecs (Pedal Electric Cycle) are designed and built in Belgium with key components sourced from local suppliers in Europe.

We prioritize quality and longevity, making bikes that are not only built to last but are also easy to repair and refurbish. By focusing on sustainability in both production and lifecycle.

The use case (UC) for Aska is about optimal component production by suppliers by optimizing batch size, cost, lead time, and quality.



2.2.1.1 Case 1: Frame - Finding and Selecting Suppliers

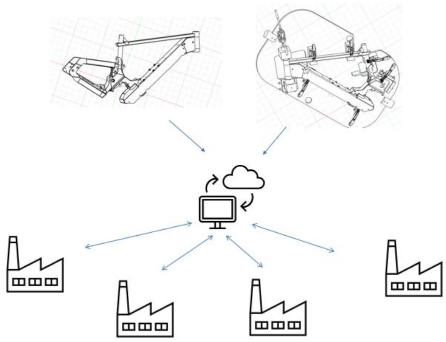
The frames for the Aska bike are designed to be compatible with standard metal processing techniques; however, these suppliers are often reluctant due to unfamiliarity with producing bike frames. Supplier will also be responsible for sourcing the raw material. A digital process description will be provided to the supplier, detailing all requirements of the production process and the final product. This ensures suppliers have a clear understanding of:

- **Production Process Requirements:** Specific steps, tools, and standards necessary to achieve consistent quality during manufacturing.
- **Final Product Specifications:** Detailed criteria for the final product, including dimensions, materials, surface treatments and performance standards.
- **Quality Standards:** Defined quality check and process for the product.

This detailed documentation will enable suppliers to provide accurate and faster quotes, as they have all the necessary information upfront.

Now tooling/fixture is a limiting factor. Specific tooling ensures every part of the frame is correctly positioned before welding. The price for a single tool is approximately €50,000, translating to €100 per bike for a batch of 500. To operate in parallel with multiple suppliers, multiple tools are required. For example: with 2 suppliers: 2 tools are necessary, with 4 suppliers: 2 tools can be circulated among them, though this requires trust.

Another option will be to evaluate the feasibility of a modular welding table with fixtures capable of meeting all horizontal and vertical requirements, with secure clamping that ensures consistent positioning during welding. The system must be easy adaptable for various products and clients, ensuring flexibility and precision across the welding operation.



2.2.1.2 Case 2: Assembly - Work Instructions

During the assembly phase, ASKA oversees the supply chain. Detailed work instructions are essential for maintaining consistency and quality during assembly.

A digital description of the assembly process will be provided, enabling even low-skilled workers to perform tasks effectively. This description will include:

- **Step-by-Step Instructions:** Clear and easy-to-follow instructions that guide workers through each stage of the assembly process.
- **Visual Aids:** Diagrams and videos to enhance understanding and ensure the correct assembly procedures are followed.
- **Quality Checks:** Built-in checkpoints for verifying the quality of each step, ensuring consistency and reducing errors.

Additionally, the digital description will serve as a training tool, allowing new employees to quickly get up to speed on the assembly process. By providing accessible, clear guidance, the system ensures that even workers with limited experience can contribute effectively and maintain high standards of quality. This will also facilitate adding assembly plant of changing assembly partner by changing demand.

2.2.1.3 Case 3: Battery - Repair, Reuse, and Refurbishment

While not a focus at present, the repair, reuse, and refurbishment of batteries will become critical in later lifecycle stages. Planning for these processes will enhance the sustainability and longevity of the batteries.

2.2.1.4 Case 4: Remanufacturing - Impact on the Supply Chain

The remanufacturing process will have significant implications for supply chain resilience. Key considerations include:

- **Disassembly:** Effective methods and instructions to break down components for reuse.
- **Component Recovery:**
  - **Frame:** several critical steps must be taken to ensure safety, functionality, and longevity of reused frames. The first step is to assess the frame for structural integrity, material suitability, and component compatibility. This ensures that the frame is in a condition suitable for reuse. Once assessed, any damage to the frame should be addressed through repairs or reinforcements, ensuring that it meets updated standards for strength and durability. Lifespan prediction techniques, including material testing and an evaluation of the frame's previous usage, can help estimate its remaining lifespan.
  - **Pinion:** investigate the possibility of reusing pinions that become available after limited usage, example after an accident or when upgrading to an electronic shifter, several key steps are needed to assess whether they can be used as refurbished components
- **Battery:** Is it possible to reuse certain components of a battery, such as the **BMS**, casing, and other parts, depending on their condition and functionality.

2.2.1.5 Case 5: DPP, Data for Homologation and Maintenance

The Digital Product Passport (DPP) plays a crucial role in:

- Documenting component serial numbers, tracker details, and lock traceability (e.g., in case of lost keys).
- Tracing assembly data, such as the Bill of Materials (BOM) and quality information, used tools.
- Provide assembly and maintenance information.
- Providing lifecycle data to support remanufacturing processes.

2.2.2 KPIS to be appointed to these goals:

	KPI	Fulfilment			KPI Description
		0%	50%	100%	
KPI-1	Lead time (months (m))	8 m	6m	3m	The average lead time in months (m) from first request to first prototype

KPI-2	Cost [%]	0	10	20	Production costs per unit must decrease by … % trough better process description and coordination between suppliers in the RAASCEMAN network
KPI-3	Quality (defect rate %)	5	2	1	The defect rate for outsourcing parts must be …% by using digital process description and integrate quality control in the RAASCEMAN network.
KPI-4	Flexibility (months (m))	5	2	1	The RAASCAMAN network must be able to respond in … months (m) to new production rates.
KPI-5	On time delivery [%]	50	70	90	The RAASCEMAN network must be able to deliver parts with a OTD … %

2.2.3 Evaluation and Acceptance Criteria

	Evaluation	**Acceptance Criteria**	**Challenge #**
KPI-1	- Measure the time between first search for a specific supplier for a component till the first prototype produced.	- This time include, supplier selection, compare different quotations, produce protype	1 2 3 4
KPI-2	- Monitor production cost, by optimising batch size, tooling, clear work instructions and process cost per component will be optimised and decreased using a RAASCAMAN network with different suppliers	- The cost per unit must decrease by…% trough better process description and coordination/competition between suppliers in the RAASCAMAN network	1 2 4
KPI-3	- Monitor the quality of the produced parts by integrate quality control in the production process and monitor the suppliers in the RAASCAMAN network	- Monitor the defect rate of products ordered in the RAASCAMAN network	1 2 4
KPI-4	- The network must be ready to react on changing demand in the bike industry due to seasonal difference in demand or other demand changes.	- The RAASCEMAN platform can react in a feasible time to changing demand in production rate, both increase and decrease in demand.	1 2 4
KPI-5	- Monitor the OTD of the RAASCEMAN platform for the different suppliers	- The RAASCEMAN platform will deliver parts on time due to clear instructions and coordination between different partners	1 2 4

2.3 Interconnected Pilot Lines

The interconnected pilot lines (testbeds) are going to be used to evaluate the RAASCEMAN concept in a safe environment where no harm can occur in a running production where potential costly damage could be caused by a malfunction in the software. Thus, the testbeds provide a unique environment consisting of remote sites, which will integrate into the RAASCEMAN MaaS platform.

2.3.1 CTU

2.3.1.1 Pilot Line Description

Figure 4 shows the architecture of the CTU demonstrator with respect to outside world and external components. The outside world is represented by other testbeds, the external components mean data processing and analytical tools, which run outside the actual production[2] environment.

The central element is a message broker, which passes different types of data/commands among other components. An example of **data flow**, which represents the **status of the production facilities** in a testbed, is the MQTT/OPCUA component in Testbed A, transmitting data to the IoT Data Platform. Another example is the IoT sensor in Testbed B, which represents a simple component being able to gather data form equipment connected internally within Testbed B, and send it to the IoT Data Platform.

Another type of communication is depicted as an arrow between the MES/Agent in Testbed A and the Message broker and represents a **data flow influencing the execution of a production sequence**, whose execution is controlled by the MES. The data for this flow may be provided by a production planner, which is depicted in the bottom left corner of the figure.

The **repository** in the figure contains models, components, resources and capabilities available in the system and provides a base for reasoning about the feasibility of execution plans, matching of required and available resources' capabilities and other similar operations. GraphDB is used to execute feasibility evaluation efficiently.

The yellow-background parts already exist at CTU as developed within previous projects.

[2] Production environment in this context means the environment of the testbed, which utilizes industrial components and is, in fact, a real-like environment.

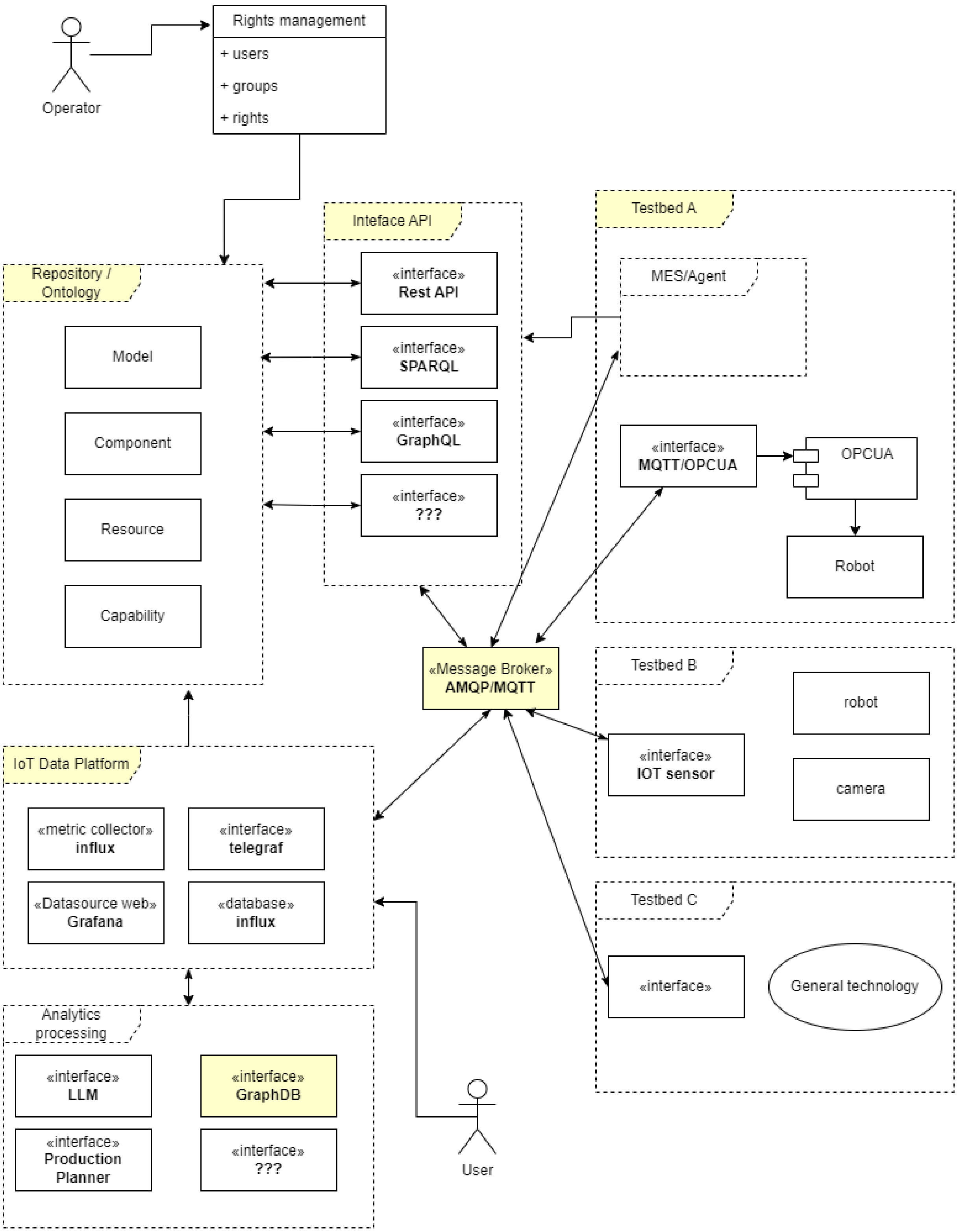


Figure 4: Architecture of the CTU demonstrator with respect to outside world (other testbeds) and additional components

Figure 5 shows the internal structure of the CTU demonstrator, which consists of several production cells, understood as individual machines. There are also mobile robots (AGVs) as part of the demonstrator which can deliver parts and assembled components among the production cells and warehouse. The AGVs have the "docking/undocking" capability to become part of the respective production cell, which it delivers the parts to/from. The Process Platform at this figure represents an MES, whose part is also a production planner to generate production sequences based on product descriptions and matching of required and available capabilities of the production resources.

The agents shown in the figure perform translation between OPC UA and MQTT to comply with the message broker of the Process Platform. Moreover, the agent can encapsulate additional features and functionality, such as transformation to AAS, link to simulation models and others.

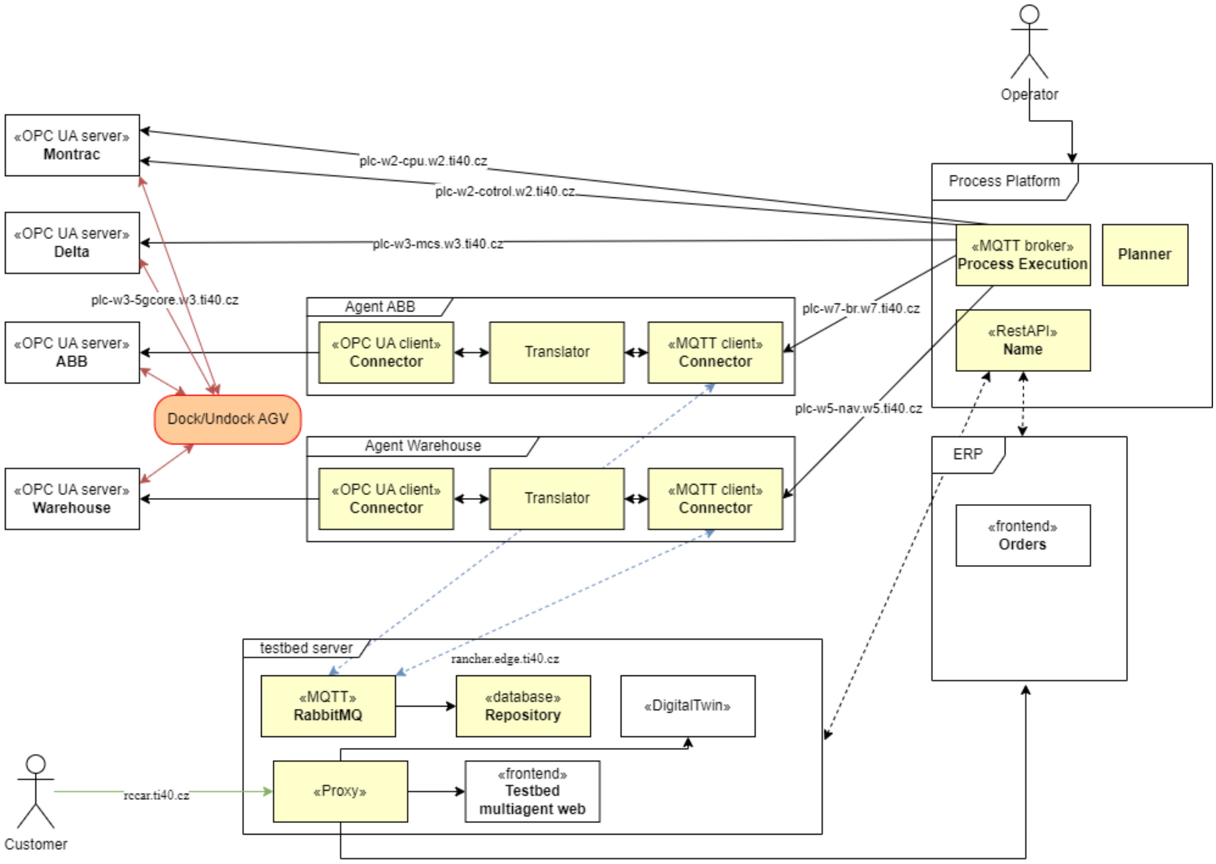


Figure 5: Detailed structure of the CTU Testbed architecture

Figure 6: Pictures of machines corresponding to those used in Figure 5

Figure 7 shows the concept of virtual production lines (digital twins), which can run in parallel with physical production lines. This concept uses the same interfaces (OPC UA) both for the virtual as well as physical components.

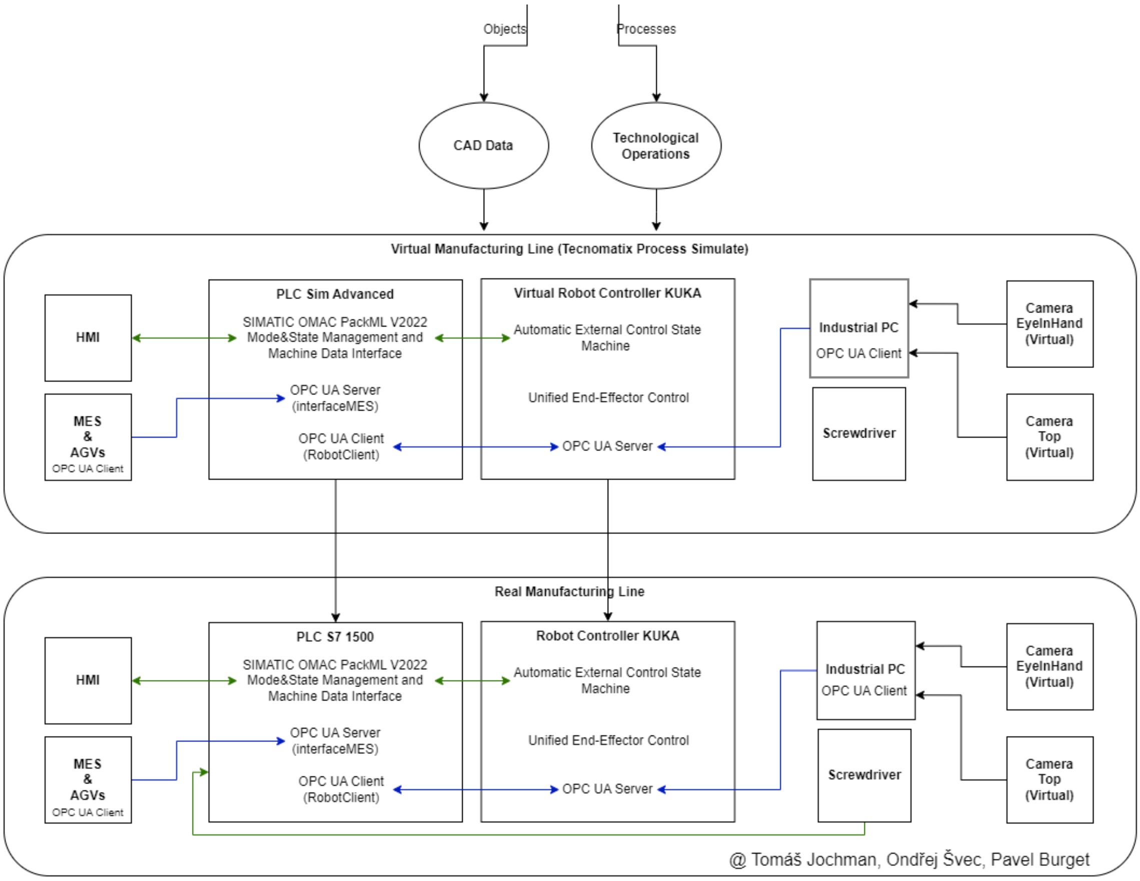


Figure 7: The concept of virtual and real production line at CTU's Testbed

This approach allows for performing high-quality simulations using virtual components and virtual controllers and then transfer the control programs from the virtual controllers to the real ones. This concept has not been fully integrated into the architecture depicted in Figure 5 but as mentioned in the text above, similarly as the agent it can be encapsulated in an AAS.

2.3.1.2 Pilot Line KPIs

	KPI	Fulfilment			KPI Description
		0%	**50%**	**100%**	
KPI-1	Ensure system components comply with the common semantic representation	50%	80%	90%	Percentage of components mapped to the defined semantic model
KPI-2	Implement communication protocols (e.g., OPC UA, MQTT) in all testbeds as an interface towards the RAASCEMAN platform.	50%	80%	100%	Percentage of nodes in the RAASCEMAN MaaS network successfully communicating via standardized protocols.
KPI-3	Reduce the time required for human decisions in unforeseen events	0%	10%	25%	Average decision-making time logged pre- and post-implementation.
KPI-4	Achieve a 90% match between planned and actual production sequences	70%	80%	90%	Percent adherence using MES logs.

2.3.1.3 Evaluation and Acceptance Criteria

	Evaluation	Acceptance Criteria	Challenge #
KPI-1	- Perform periodic audits to check compliance of system components with the semantic model using automated validation tools - Use benchmarks to assess the mapping of existing resources and components to the semantic structure.	- At least 90% of the system components are successfully mapped to the defined semantic model. - Automated validation scripts report zero critical errors in the mappings.	1
KPI-2	- Conduct integration tests for all nodes in the system to verify communication compatibility using selected protocols. - Use message flow logging to ensure uninterrupted data exchange between the testbeds and the RAASCEMAN platform.	- 100% of nodes in the system successfully exchange data using standardized protocols. - No critical communication failures during three consecutive stress tests.	2
KPI-3	- Compare pre- and post-implementation decision-making times using logs from the decision-support tools. - Collect feedback from operators to measure perceived improvement in decision-making processes.	- Average decision-making time is reduced by at least 25% compared to baseline. - 80% of operators report satisfaction with the decision-support tools in post-implementation surveys.	3
KPI-4	- Analyze MES logs to compare planned vs. executed production sequences. - Conduct reviews with each new version of the planner to identify deviations and validate adjustments made by the production planner.	- A 90% match between planned and actual production sequences	5

2.3.2 RPTU

2.3.2.1 Pilot line description

The demonstrator from the RPTU showcases an innovative assembly and disassembly process using two collaborative robots, each mounted on a separate module. Motion planning is efficiently handled for each robot by a Distributed Model Predictive Controller (DMPC). A vision system, installed on the side and top of the robots, enables object detection on the table and human presence recognition. The robots operate autonomously within the same environment, ensuring seamless collaboration, cooperation and collision-free interaction.

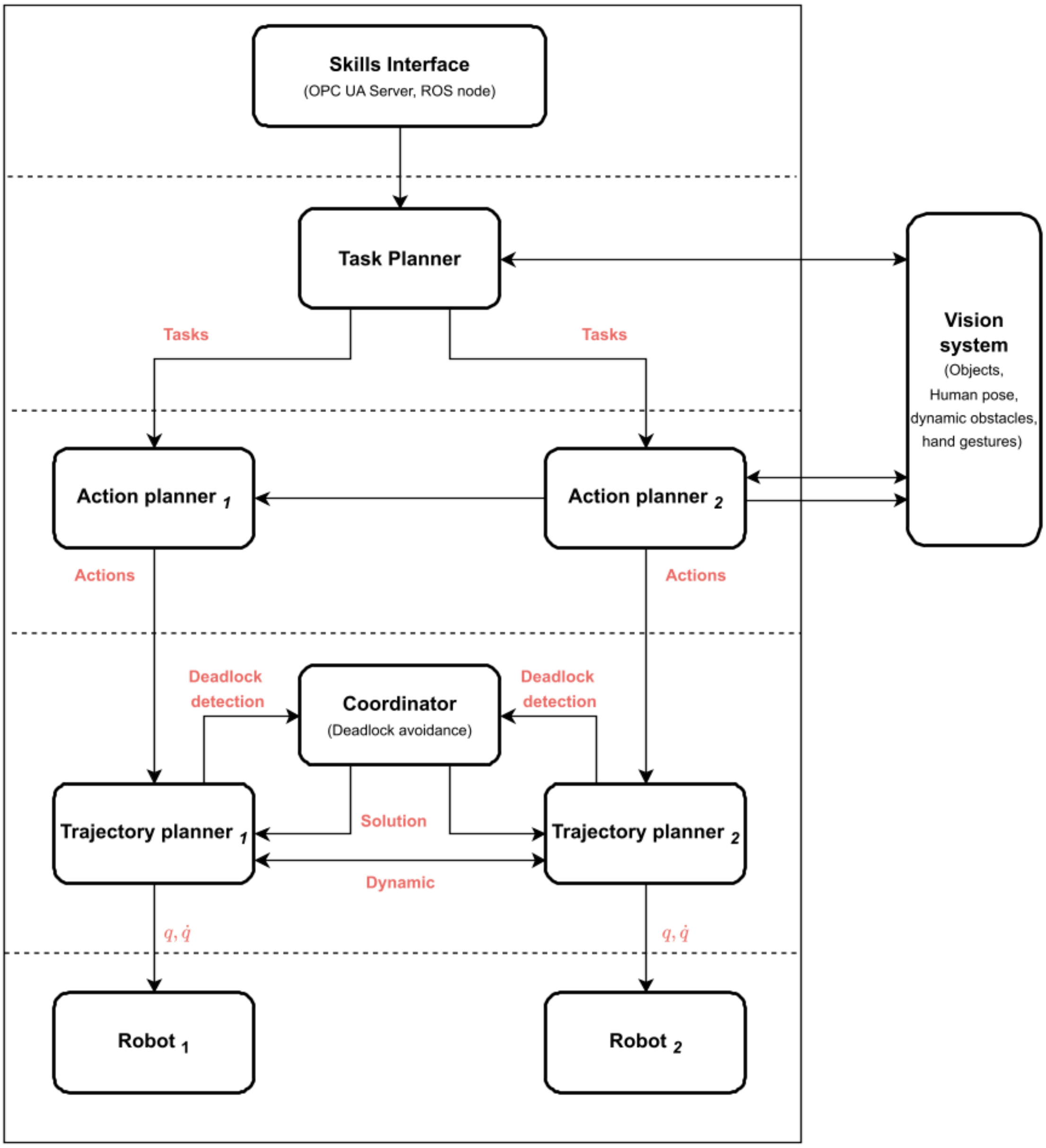


Figure 8: System architecture of the KoKoBot-Demonstrator

The Figure 8 depicts the system architecture of the KoKoBot-Demonstrator. It showcases a hierarchical design for multi-robot coordination, focusing on efficient task execution and deadlock avoidance. The **Skills Interface** connects external platforms, such as OPC UA Servers or ROS nodes, to receive tasks, which are then managed by the **Task Planner**. This planner decomposes tasks and assigns them to the respective **Action Planners** for each robot. The **Action Planners** collaborate with the **Vision System** to consider environmental factors like objects, obstacles, and human presence. These actions are translated into motion plans by the **Trajectory Planners**, which are monitored by a **Coordinator** to detect and resolve potential deadlocks. Finally, the robots execute the planned trajectories dynamically, ensuring seamless and adaptive operation. This architecture enables a robust framework for purely cooperative robotic systems or even a collaborative infrastructure between a robot and a human.

Figure 9: Real image of the KoKoBot-Demonstrator

The Figure 9 represents **KoKoBot,** which is a state-of-the-art platform designed to advance research and innovation in collaborative robotics. It features an assembly and disassembly process utilizing two **Universal Robots UR5e**, mounted on separate modular stations, to perform tasks autonomously and efficiently within a shared workspace. These robots leverage **DMPC** for motion planning as described previously, ensuring optimized trajectories and collision-free interactions. The system is modular and scalable, making it a versatile tool for exploring robotic cooperation and dynamic task execution.

Central to the demonstrator is its sophisticated vision system, which includes 3 **ZED 2i stereo camera** installed on the side and top of the module. This enables precise object detection on the workspace and human presence recognition, ensuring safe and effective collaboration. The setup also integrates a user-friendly **Human-Machine Interface (HMI)**, allowing operators to assign tasks, monitor operations, and make real-time adjustments with ease. By combining advanced robotics, vision systems, and intuitive user interaction, the KoKoBot embodies the future of collaborative robotics, promoting seamless human-robot interaction in both industrial and research environments.

2.3.2.2 Pilot Line KPIs

	KPI	Fulfilment			KPI Description
		0%	**50%**	**100%**	
KPI-1	Ensure system components comply with the common semantic representation	50%	80%	90%	Percentage of components mapped to the defined semantic model
KPI-2	Implement Language4.0 interaction protocols for the negotiation with the other pilot lines of the demonstrator in MaaS scenario.	50%	80%	100%	Percentage of nodes in the RAASCEMAN MaaS network successfully communicating via standardized protocols.
KPI-3	Parameterizable interface	50%	80%	100%	Send a new production plan and start its execution on the production line by setting a few parameters via the interface.
KPI-4	Send instruction to a GUI	50%	80%	100%	The worker gets the information about the task on the GUI and gives feedback to the system when he or she starts the task.
KPI-5	Human-Robot-Interaction	20%	50%	80%	Collision-free cooperation between robot and worker, where the worker is never injured by the robot.

2.3.2.3 Evaluation and Acceptance Criteria

	Evaluation	Acceptance Criteria	Challenge #
KPI-1	- Perform periodic audits to check compliance of system components with the semantic model using automated validation tools - Use benchmarks to assess the mapping of existing resources and components to the semantic structure.	- At least 90% of the system components are successfully mapped to the defined semantic model. - Automated validation scripts report zero critical errors in the mappings.	1
KPI-2	- Conduct integration and interaction tests for the defined MaaS scenarios using selected protocols. - Use message flow logging to ensure uninterrupted data exchange between the testbeds and the RAASCEMAN platform. Use logging to ensure correctness of the implemented protocols.	- 100% of nodes in the system successfully exchange data using standardized protocols. - No critical communication failures during three consecutive stress tests.	2
KPI-3	- Implement an interface on a standardized communication protocol with parameters that make the task executable. - Demonstrate task changes by sending a new task with only a few parameters.	- 100% of changing the task by sending a few parameters	5

	Evaluation	Acceptance Criteria	Challenge #
KPI-4	- Visualize and describe the task on a screen with a live stream from the cameras and highlighted tasks. - Collection of feedback from different users as a measure of understanding of the task	- 80% of users report satisfaction with visualisation and task description	5
KPI-5	- Simulation of the avoidance of collisions between a human being and a robot. - Demonstration of the avoidance of collisions between a human being and a robot.	- 80% of the simulations will bring the robot to avoid the collision or to stop the robot if it is not possible to use a other strategy.	5

2.3.3 DFKI SmartFactoryKL

2.3.3.1 Pilot line description

The DFKI SmartFactoryKL demonstrator, which is shown in Figure 10 and called "Production Island _KUBA" is part of the large demonstration landscape for testing and showcasing the concepts of the Shared Production in the scope of the Industry 4.0. While the transportation system is in the centre, different modules can be attached via Plug-and-Produce with the help of the standard mechanical, electrical and communication interfaces. Supplied components such as trailer bodies or driver's cabs are fed in via a docking station. A modular module prints individual trailer bodies in 3D. Part of the modular module is also a manual workstation where the pre-assembly of the semi-trailer and trailer takes place. A robot arm takes over the in-feeding and out-feeding of the components. The chassis for pre-assembly are temporarily stored directly at the manual workstation. The 'quality control' module checks all components that are fed in and assembled on _KUBA. Object and anomaly detection methods from the field of artificial intelligence are used for quality assurance. The control of _KUBA is implemented using a multi-agent system. The produced trucks can be customization to a high degree by the customers.

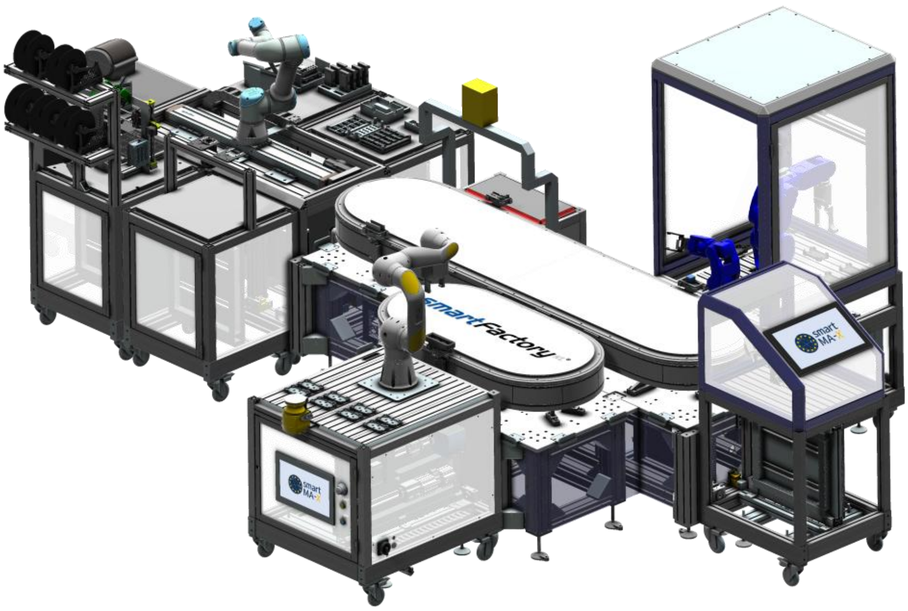


Figure 10. DFKI SmartFactory Demonstrator “Production Island _KUBA”

As noted earlier, the demonstrator is a part of the Shared Production use case. The high-level view on its architecture is shown in Figure 11. Each cyber-physical production module (CPPM) of the demonstrator has the standard OPC UA information model that represents it in the cyber space. This OPC UA model, which is shown in Figure 12, is the single interface through which the module can interact with the external world. It provides all the necessary monitoring and life-cycle data about the module and its technological process. Furthermore, the model provides the standard access to the module’s functionalities through the so-called skills. In our CPPM’s design we are following the skill-based engineering approach (Köcher, et al., 2023), according to which every function of a module is encapsulated as a software component with the standard behaviour, modelled as a state machine, and the standard interface. This improves modularity and interoperability of the control software.

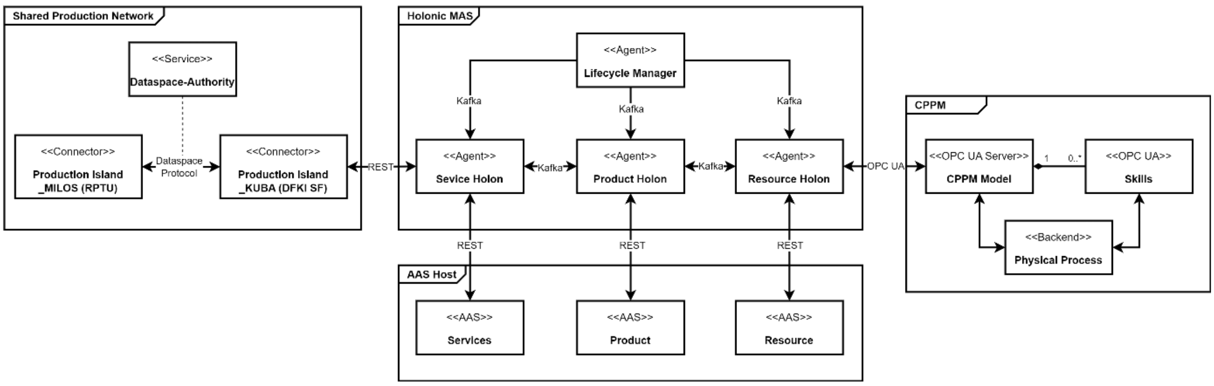


Figure 11. Block diagram of the Shared Production Demonstrator at DFKI[3]

[3] https://ifs.dfki.de/insel_pl4_acopos/architecture

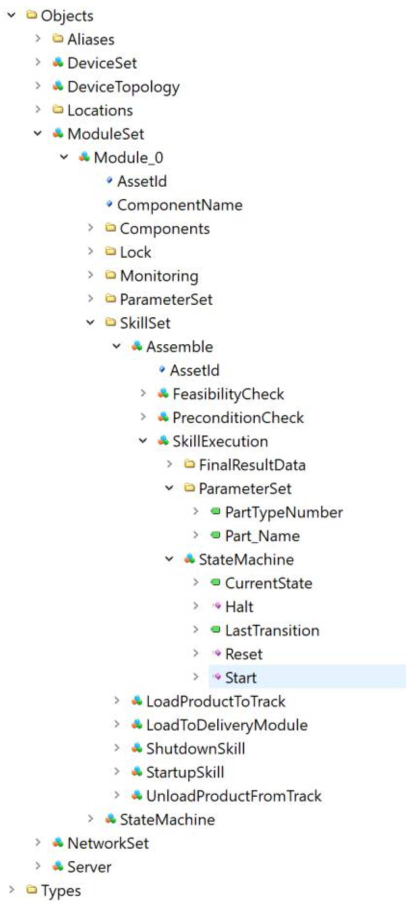


Figure 12. OPC UA Model of the Cyber-Physical Production Module

The second block of the architecture is the holonic multi-agent system that realizes semi-heterarchical, also known as holonic control system of the demonstrator. It consists of four major holonic agents. Holonic means that such agents can recursively consist of the other similar agents. The Resource Holon executes a production recipe at a time and controls its CPPM through OPC UA interface. It provides the relevant machine data, e.g., topology, information about module's skills, etc. The Product Holon is used to retrieve data about the produced product from the Product AAS and make order to the Resource Holons to initiate production. The Service Holon manages data access to the IDS connector and takes part in the Shared Production negotiations. The last agent, namely Lifecycle Manager manages the work of the system and provides interface to the users. Detailed architecture description can be found in (Bernhard, et al., 2024). Each asset in our system has the standard digital representation via its AAS. The figure shows the AASs only for the Holons. The AASs serve the single sources of truth and provide all the information about their assets in machine readable way together with the semantic descriptions. The last block in Figure 11 is the Shared Production network. The Service Holon uses the RAST API to interface the EDC connector[4] which connects the _KUBA demonstrator with the production islands in the Shared Production Data Space.

[4] https://github.com/eclipse-edc/Connector

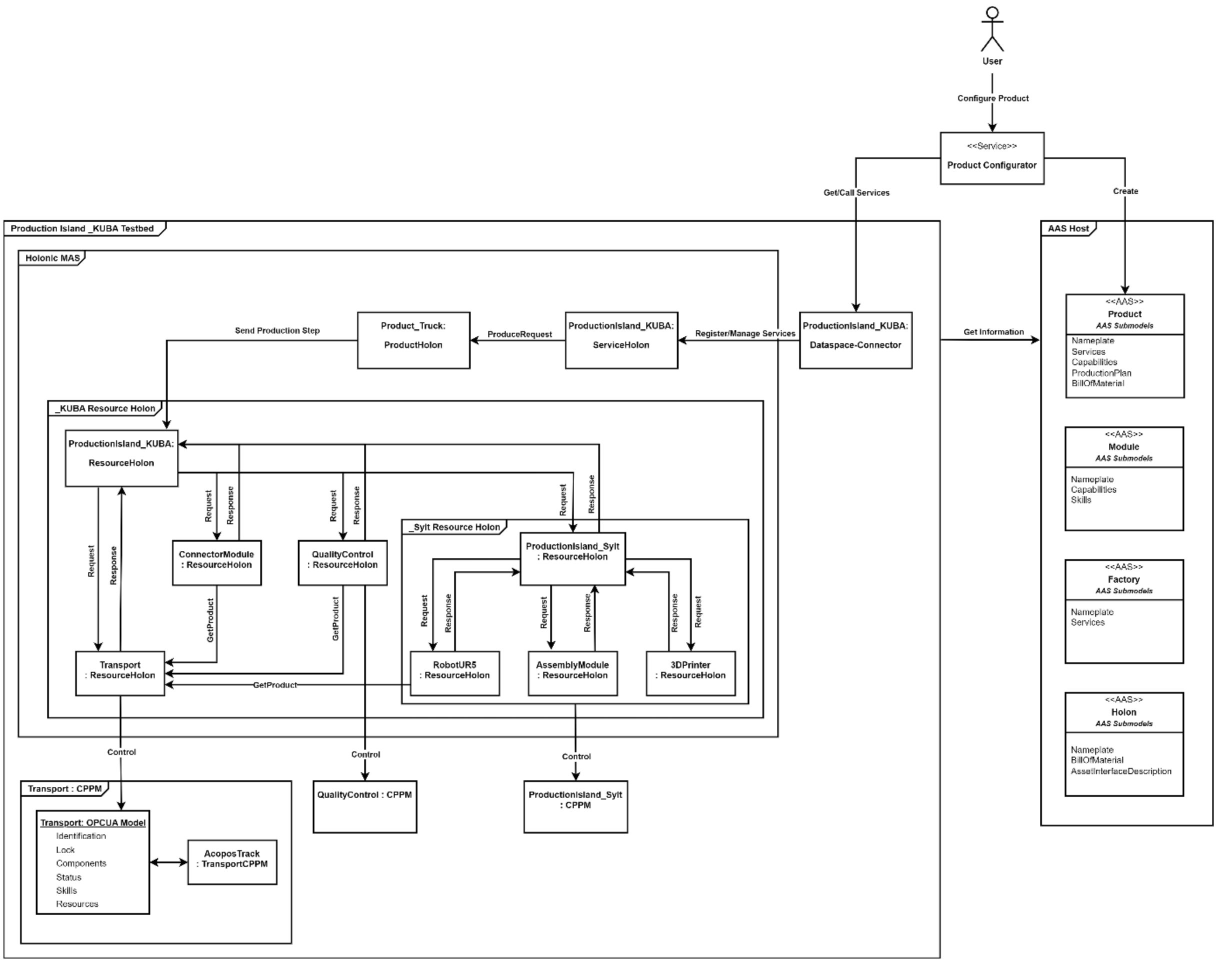


Figure 13. Detailed architecture of the "Production Island _KUBA"[5]. simon.jungbluth@dfki.de

Figure 13 shows more detailed view on the architecture of the "Production Island _KUBA". A user can configure its product through the Product Configurator that creates the AAS of the required product. The user can also call manufacturing services via the Product Configurator and the Shared Production network. The service call through the EDC gets to the Service Holon of the _KUBA. After successful negotiation, the Service Holon generates the request to the Product Holon with the ID of the required Product AAS. After getting all the required information about the product, the Product Holon starts the production process by sending production steps to the _KUBA Resource Holon. The _KUBA Resource Holon consists of a set of subholons each representing its production module. They collectively produce the required product. The Figure 13 shows the interactions between the holons during production. Each Resource Holon controls its CPPM through the OPC UA.

[5] https://ifs.dfki.de/insel_pl4_acopos/architecture

2.3.3.2 Pilot Line KPIs

	KPI	Fulfilment			KPI Description
		0%	50%	100%	
KPI-1	Ensure system components comply with the common semantic representation	50%	80%	90%	Percentage of components mapped to the defined semantic model
KPI-2	Implement Language4.0 interaction protocols for the negotiation with the other pilot lines of the demonstrator in MaaS scenario.	50%	80%	100%	Percentage of nodes in the RAASCEMAN MaaS network successfully communicating via standardized protocols.
KPI-3	Achieve 90% of correct results by auditing a manufacturing service.	50%	70%	90%	Percentage of correct answers from the audit tool.
KPI-4	Achieve 90% of correct results from the recommendation engine by the generation of the valid supply chains.	50%	70%	90%	Percentage of correct answers from the recommendation engine.

2.3.3.3 Evaluation and Acceptance Criteria

	Evaluation	Acceptance Criteria	Challenge #
KPI-1	- Perform periodic audits to check compliance of system components with the semantic model using automated validation tools - Use benchmarks to assess the mapping of existing resources and components to the semantic structure.	- At least 90% of the system components are successfully mapped to the defined semantic model. - Automated validation scripts report zero critical errors in the mappings.	1
KPI-2	- Conduct integration and interaction tests for the defined MaaS scenarios using selected protocols. - Use message flow logging to ensure uninterrupted data exchange between the testbeds and the RAASCEMAN platform. Use logging to ensure correctness of the implemented protocols.	- 100% of nodes in the system successfully exchange data using standardized protocols. - No critical communication failures during three consecutive stress tests.	4
KPI-3	- Compare the answers from the audit tool with those from the experts..	- .At least 70% of the answers from the audit tool are confirmed by the experts.	4
KPI-4	- Compare the answers from the recommendation engine with those from the experts.. -	- At least 70% of the answers from the recommendation engine are confirmed by the experts. - The proposed supply chains are feasable in the MaaS network.	4

2.3.4 FM

2.3.4.1 Pilot line description

The Flanders Make Infraflex infrastructure shown in Figure 14 is developed as an open architecture of multiple reconfigurable work cells. This infrastructure is designed to enhance flexibility in assembly processes and allows for rapid reconfiguration, enabling efficient assembly and disassembly of products with high-mix, low volume. Each cell consists of a base part with a robot mounted on the cell and a turning table to allow for in cell moving of parts. The flexibility and adding of certain capabilities come from the modules (up to six add-ons can be attached to one cell) that can be added on the fly to the system (e.g. toolchangers, local storage, bin picking, digital operator assistance systems…).

A key feature of Infraflex is its skill-based programming framework, which decomposes assembly tasks into fundamental skills, such as grasping or moving objects. This skill based approach simplifies robot programming, allowing for quick adaptation to new tasks and products.This skill-based approach simplifies robot programming, allowing for quick adaptation to new tasks and products.

Infraflex supports human-robot collaboration by integrating manual assembly add-ons equipped with digital work instructions, projected to assist operators. This integration enhances operator training and productivity, contributing to a more flexible and efficient assembly environment.

Figure 14. Flanders Make Infraflex demonstrator

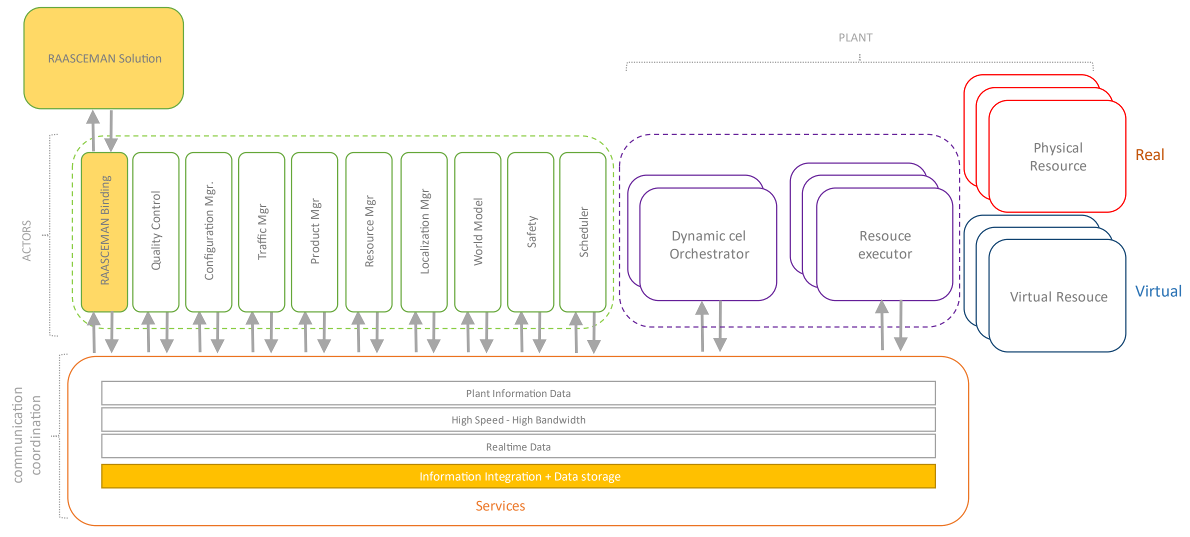


Figure 15 Flanders Make Manufacturing assembly system - Infraflex

Figure. 15 provides an overview of the components within the Infraflex system. The Infraflex setup employs a hierarchical service-oriented approach to manage production operations. Changing or improving any of the actors in the system should not have an impact on the other actors.

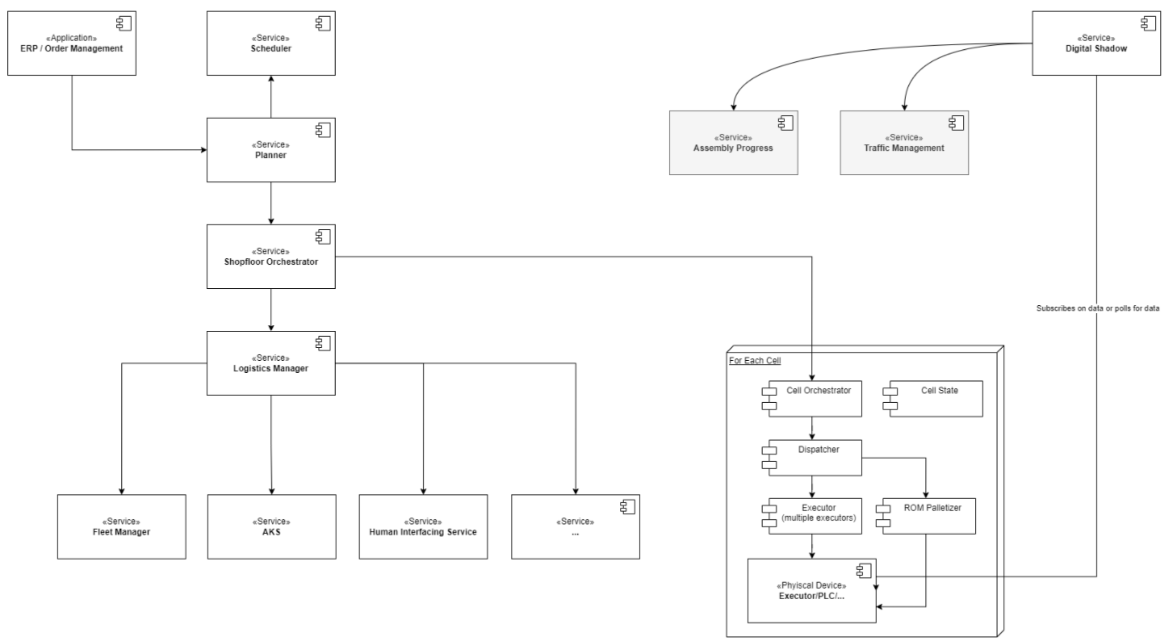


Figure 16 Infraflex high-level architecture

As shown above in Figure 16, the shopfloor orchestrator passes the instructions to the appropriate Infraflex assembly cell and coordinates with multiple downstream services such as a mobile robots Fleet Manager, AKS (Automated Kitting Service), Human Interfacing Service etc to move things between different locations.

Each individual Infraflex cell contains a control hierarchy consisting of a Cell Orchestrator, Cell State manager, Dispatcher, and Executor. The Executor is the common interface to connect with the hardware. The Executor can accept commands and data requests through ROS2 and REST API. For publishing data Infraflex cell also supports MQTT. The executor is the only hardware/vendor aware component, all other components are supposed to be vendor and hardware agnostic.

The Digital Shadow service gets its data from the different actors and orchestrators and enables near real-time monitoring (current state, execution time, historical/pending tasks).

As part of the RAASCEMAN project, we will introduce a new actor – *Raasceman Binding* that interfaces Infraflex with the RAASCEMAN platform.

The recipe for the orchestrator is defined with an aim to build flexible, reconfigurable manufacturing operations management systems.

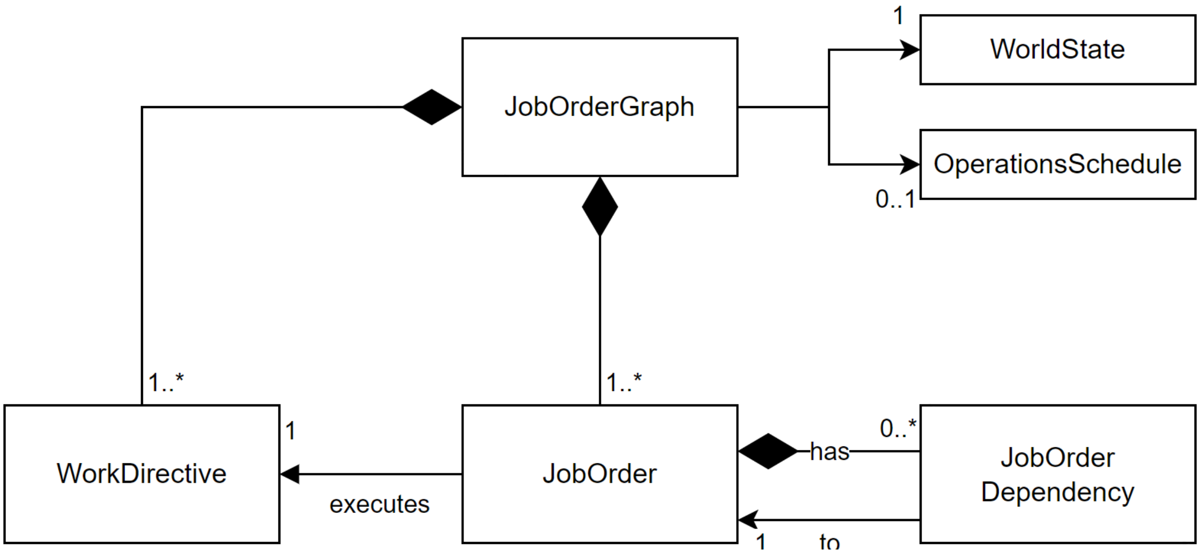


Figure 17 Job order flowchart

Figure 17 shows the components of a job order graph and Figure 18. below shows the job order graph example with dependencies and work directives.

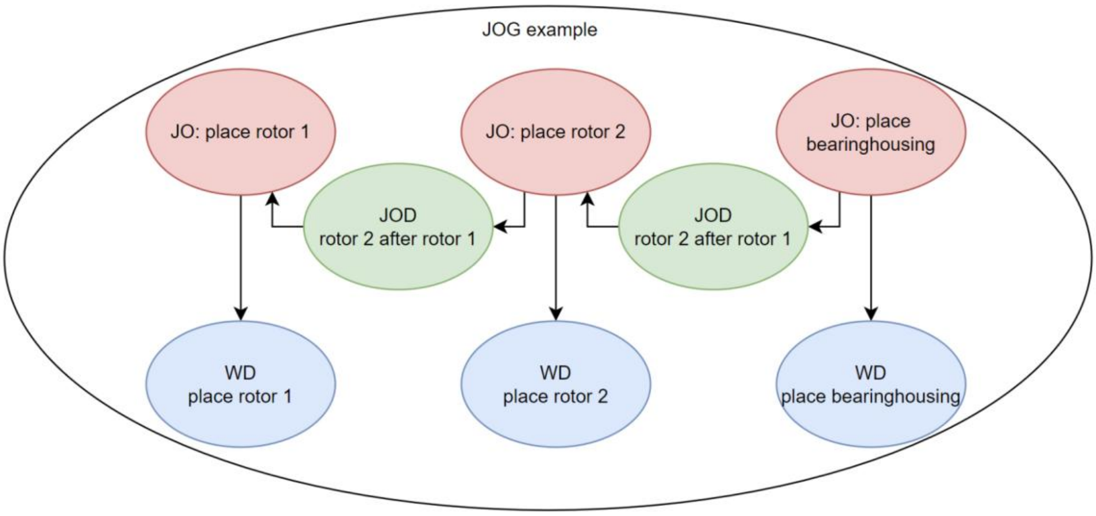


Figure 18. Job order graph example

A Fleet Management System will bring flexibility through mobility. This integration will enhance the coordination of autonomous mobile robots (AMRs) within the manufacturing environment, ensuring efficient and safe operations.

The Fleet Management System will leverage the VDA5050 communication protocol and legacy REST API communication for AMRs not supporting VDA5050. This will allow to easily add AMRs to respond dynamically to production demands while ensuring optimal utilization of resources.

Next to this, the Real-Time Location System (RTLS) will be further enhanced with improved position tracking capabilities using Ultra-Wideband (UWB) technology. Anchor nodes and sensor fusion techniques (with camera tracking e.g.) will provide precise localization data. The data collected is communicated over MQTT. This near real-time visibility will improve coordination between different components of the manufacturing process and provide the necessary date for digital shadows.

2.3.4.2 Pilot Line KPIs

KPI	KPI Title	Fulfilment			KPI Description
		0%	50%	100%	
KPI-1	Semantic model compliance	50%	80%	100%	Percentage of relevant components mapped to the defined semantic model to ensure consistency in InfraFlex.
KPI-2	Implement Language4.0 interaction protocols for the negotiation with the other pilot lines of the demonstrator in MaaS scenario.	50%	80%	100%	Percentage of relevant nodes in the RAASCEMAN MaaS network successfully communicating via standardized protocols.
KPI-3	Infraflex availability/ capability check	50%	80%	100%	Percentage of product orders received from RAASCEMAN (compatible with internal format) where Infraflex can provide inputs regarding availability of parts and capability. This KPI is tentative and depends on the product orders

KPI-4	Percentage of Infraflex's assets which can provide feedback to RAASCEMAN regarding live asset positions and high-level status.	25%	50%	80%	Percentage of Infraflex's assets which can provide feedback to RAASCEMAN regarding live asset positions and high-level status.
KPI-5	Escalation service to RAASCEMAN network in case operator/supply chain intervention is required (for e.g. spare parts)	Level1	Level2	Level3	Levels to which Infraflex can escalate the assembly tasks which cannot be handled. Level 1: Internal escalation; Level 2: Shop floor level; Level 3: RAASCEMAN level

2.3.4.3 Evaluation and Acceptance Criteria

KPI	Evaluation	Acceptance	Challenge
KPI-1	Perform periodic audits to check compliance of system components with the semantic model using automated validation tools Use benchmarks to assess the mapping of existing resources and components to the semantic structure.	- 100% of relevant components are successfully mapped to the defined semantic model. - Automated validation scripts report zero critical errors in the mappings.	1
KPI-2	Conduct integration and interaction tests for the defined MaaS scenarios using selected protocols. Use message flow logging to ensure uninterrupted data exchange between the testbeds and the RAASCEMAN platform. Use logging to ensure correctness of the implemented protocols.	- 100% of relevant nodes in the system successfully exchange data using standardized protocols. - No critical communication failures during three consecutive stress tests.	4
KPI-3	Ensure that the received product order from RAASCEMAN follows the format required for InfraFlex. Ensure that Infraflex can communicate availability and capability for the particular task Track instances where human intervention is required to correct inputs.	- For 100% of product mixes infraflex can provide inputs regarding availability and capability. If infraflex has capability the recipe, assembly instructions can be generated. - No errors related to format of request received from RAASCEMAN platform	5
KPI-4	Ensure that all InfraFlex assets are registered and uniquely identifiable in RAASCEMAN. Message flow logging to ensure all assets can report basic operational states (idle, working, error). Validate that real-time asset data is correctly reflected in the RAASCEMAN platform	- At least 90% of InfraFlex assets are uniquely identified and registered in RAASCEMAN. - At least 90% of Infraflex assets can report status and live position	2

KPI-5	Level 1: Measure the success rate of escalation to the operators at cell level. Level 2: Measure the success rate of escalations at the shop floor level. Level 3: Measure of successful escalations of issues to the RAASCEMAN network.	-100% success rate of escalating the intervention requirement to RAASCEMAN network level -Max 10% false escalations	3

2.4 Summary of KPIs, evaluation methods and acceptance criteria

This table below summarizes the Key Performance Indicator (KPI) categories across the RAASCEMAN project, outlining their objectives, evaluation methods, and acceptance criteria. The evaluation methods combine quantitative data analysis, simulation-based validation, and qualitative user feedback, ensuring a comprehensive assessment of system performance and resilience.

Category	Category Description	Evaluation Methods	Acceptance Criteria
Production Efficiency KPIs	Focus on improving production output, minimizing deviations from planned targets, and enhancing equipment effectiveness through automation and optimization.	- MES/ERP data analysis to compare planned vs. actual output - Digital twin simulations for performance validation - Predictive model accuracy checks	- Consistent reduction of deviations from production plans - High accuracy in predictive performance models
Supply Chain Resilience KPIs	Aim to strengthen supply chain reliability through improved on-time delivery, reduced lead times, and enhanced supplier coordination.	- ERP-based tracking of supply chain performance - Time-based analysis for lead time reduction - Supplier performance reviews	- High percentage of on-time deliveries - Lead times consistently reduced to target thresholds
Interoperability KPIs	Measure the ability of different systems to communicate seamlessly through standardized protocols and ensure compliance with semantic models.	- Integration tests with standardized protocols (e.g., OPC UA, MQTT) - Automated semantic compliance audits - Data exchange stress testing	- Full interoperability across system nodes - High compliance with semantic models and data standards
Decision-Making KPIs	Assess the effectiveness of decision-support systems in reducing human decision-making time and improving overall process efficiency.	- Decision log analysis to compare pre- and post-implementation performance - Operator feedback and usability studies	- Significant reduction in decision-making times - High levels of operator satisfaction and adoption

3 Conclusion

This deliverable provides a comprehensive overview of the key demonstrators within the RAASCEMAN project, detailing their structure, objectives, and the evaluation framework designed to measure their effectiveness. As a supplementary document to D1.1, it expands on the initial concepts by offering in-depth descriptions of the Automotive Use Case (Continental), the Bike Production Use Case (ASKA Bikes), and the Interconnected Pilot Lines (CTU, DFKI, RPTU, FM). These demonstrators not only serve as practical environments for testing the developed solutions but also as essential drivers for defining the requirements of the RAASCEMAN common software platform.

The deliverable outlines how the use cases serve as the foundation for evaluating the MaaS concepts, ensuring that the platform addresses real-world manufacturing challenges. The KPIs defined for each use case are directly linked to the key challenges identified in the project proposal, such as enhancing supply chain resilience, improving interoperability through semantic models, supporting real-time decision-making, and enabling adaptive production planning. The evaluation framework combines real-time monitoring, digital twin simulations, operator feedback, and stress testing to ensure that the platform meets the performance expectations and acceptance criteria specific to each demonstrator.

Furthermore, the document introduces the communication interfaces and data models that form the basis for integrating the RAASCEMAN results into a cohesive, overarching software platform. These technical foundations are critical for enabling seamless data exchange, system interoperability, and the scalability of the RAASCEMAN platform across diverse industrial environments.

By establishing clear evaluation criteria and linking them to the broader project objectives, D1.2 ensures that the RAASCEMAN platform will be rigorously tested and refined based on the insights gained from real-world applications. This deliverable not only contributes to the project's technical roadmap but also lays the groundwork for future deliverables focused on system integration, validation, and large-scale deployment. Ultimately, the outcomes of these evaluations will support RAASCEMAN's goal of enabling flexible, resilient, and intelligent manufacturing networks that can adapt to dynamic global supply chain conditions.

4 References

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