List interface and connected equipment in the production area

Deliverable 6.1

MUWO

MULTI-METHOD WORKSPACE FOR HIGHLY SCALABLE PRODUCTION LINES

Public

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Abstract	This document includes first version of MUWO list of interfaces, machines, protocols, data sources and architecture for interoperable information systems for use in the project. The purpose of this architecture is to define data journey, related entities and relationship between other intelligent components will be developed within the project
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1.0	11/11/2021	ACD	Deliverable structure and Turkish use case information
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1.2	17/01/2022	ACCURO	Spanish use case information
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1.3.1	27/01/2022	ACCURO	Final document editing and formatting.
1.2	28/01/2022	ISEP	Update on Portuguese use case

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1. Introduction

MUWO has objective on the development of technologically reconfigurable and capacitive scalable process modules for product assembly with high variance. With development of MUWO standards regarding to material and information flows. Information exchange process is important for each module inside project modules. With enabling data exchange and defining interface standards in platform, each process modules can be carried out differently with little effort in a quick way without having reactively adapt different design features and areas. In this manner, in Deliverable 6.1, interfaces and connected equipment in in use case scenarios are given with objectives and relation with the technical requirements.

This document includes first version of MUWO list of interfaces, machines, protocols, data sources and architecture for interoperable information systems for use in the project. The purpose of this architecture is to define data journey, related entities and relationship between other intelligent components will be developed within the project. With the agreement on Deliverable 6.1, analysis of the software interfaces makes the first step on connection of majority of the toolchain for the MUWO platform.

1.1. Document structure

Work package 6 has the overall goal to integrate the individual contents of the work packages and to build up the demonstrators in consultation with the end users. Deliverable 6.1 has four main sections; 1) objectives and scenario requirements, 2) application architecture and interfaces, 3) connected equipments and 4) interfaces. In the first section of the deliverable, for each use case, objectives and scenario requirements are explained with explaining technical challenges. Introducing physical devices and its related components like sensors, communication protocols, objectives and scenario requirements and use case base architecture including work flow between physical resources and digital structures of the smart decision system. With given information on connection equipment and test cases and integration of modules will be planned for MUWO platform.

2. Relation, Interfaces and Connected Equipment

In plan of integration of different modules and creating demonstration plans, Work package 6 has focuses on analysing, integration and demonstration of project objectives. Deliverable 6.1 provides first milestones for description of production, smart hardware & software interfaces and description of industrial processes. In the following section, applications scenario requirements related to technical requirements are explained for each use cases. In following connected equipments are explained with protocols and standards in communication with other modules. Lastly in the next part, Software and Hardware interfaces are introduced for each of the use cases in aim of integration and demonstration of the MUWO technologies.

2.1. Objectives & Scenario Requirements

2.1.1. UC1 - IDEPA's Use Case (Portugal)

For MUWO project, the section in analysis is the jacquard Loom where:

- 4 industrial loom machines will be used, placed in the Jacquard Loom section, and placed distinct types of sensors in different areas of the machine
- These sensors are going to constantly be sending data to a **Smart Box** (edge processing device with embedded OPC-UA data serving capabilities)
- The data received by the Smart Box will then be sent to the **Sensor Data API**, which will forward them to a **SQL Database,** being part of the **Data Platform**
- This data received from the data platform and other sources is then sent to an **Industry data relay** which funnels it to the **Equipment Health Monitor System(EHMS)** and to the **Predictive Set**
- The **Predictive Set** is composed by a Scheduling Algorithm, a Predictive Maintenance Algorithm and Quality Prediction Algorithm.
- This data is then moved to the **Autonomous Action Broker (AAB)** forwarding to the EHMS.

Table 1. Application scenario requirements and related technical requirements for Use-case 1 (Portugal)

Application Scenario Requirement ID	Application Scenario Requirements	Related Technical Requirement	Partner
UC1-SR_DATAWARN	• System must present data from the sensors and send warning notifications when pre-defined thresholds are surpassed	UC1_SisTrade_PT_1 UC1_SisTrade_PT_2 UC1_SisTrade_PT_6 UC1_SisTrade_PT_7	SISTRADE
UC1-SR_DATAFLOW	• Sensor and external data must be homogenized into the data relay to the EHMS and Predictive set	UC1_SisTrade_PT_1	SISTRADE
UC1-SR_PRED	• System must acquire the certain amounts of data from the	UC1_SisTrade_PT_4	ISEP

	specific sources to create and calibrate predictive algorithms		
UC1-SR_SCHED	• The scheduling algorithms must present simulated benefits before application	UC1_SisTrade_PT_5	ISEP
UC1-SR_QUAL	• Quality prediction algorithms must be tested in parallel with the process before full integration	UC1_SisTrade_PT_3	ISEP

2.1.2. UC2 - GTF Rotor Cell Operation (Turkey)

In the MUWO Project, it is aimed to select the best simulation variant for automating factory processes and applying them to the real factory environment by creating automated simulations. In this context, works will be carried out on simulation environments that are exactly suitable for the real factory environment and the use of robotic vehicles that will work instead of humans in this environment (Figure 1 and Figure 2Figure 2).

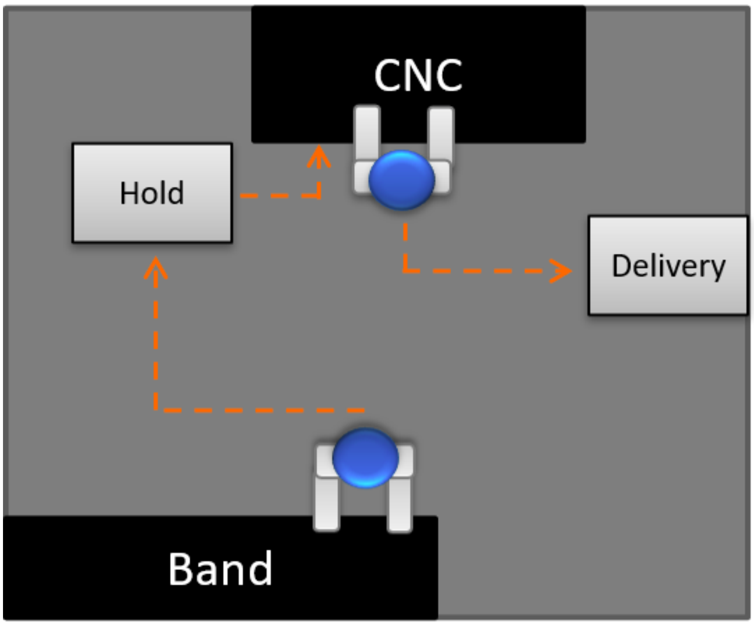

Figure 1. Example factory demonstration

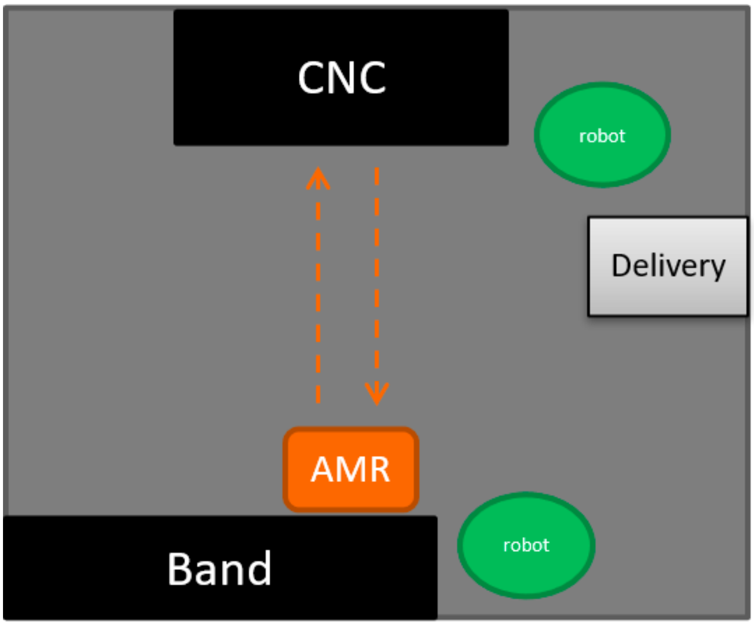

Figure 2. Example automated factory environment with robots demonstration

Table 2. Application scenario requirements and related technical requirements for Use-Case 2 (Turkey)

Application Scenario Requirement ID	Application Scenario Requirements	Related Technical Requirement	Partner
UC2-SR_1_AMR	• The trajectory plans must conform the position/velocity/accerelation/jer+k limits of the robot's joints. • The robot should implement a local trajectory plan to reach target points by avoiding obstacles. • Robot tool center point coordinates and speed available Information about the robot tool state (on or off) and robot input output signals available • In the simulation environment; The robotic system must not respond to any external remote-control command or condition that causes a hazardous situation. • The servo motor is operated at the user-defined speed and direction	UC1_INO_TR_5, UC1_INO_TR_7,	Inovasyon

	• The motor speed and direction can be set by the remote-control application		
UC2-SR_2_Coms	• Given software versions should be used for each software system: Docker 20.10.5, Docker-compose 1.25.4, Python 3.6, Flask 2.0.1, Elastic Search 7.9.2, Kibana 7.9.2, React 17.0.2, Express 4.17.1, Logstash 7.9.2, Grafana 7.3.3 (Ubuntu), Orion 3.0, MongoDB 4.0, cratedb 4.1.4 • Draco service should be integrated for data subscription. Preliminary installations are also required for quantum-leap. • Latest version of Postgres should be installed. • Minimum 8-CPU cores, 8 gb RAM, Deep learning operatable GPU and 500 gb of Data storage and Ubuntu 20.04 LTS is needed in Operation of Middleware system.	UC1_ACD_TR_1, UC1_ACD_TR_2	ACD
UC2-SR_1_Ind_Robot	• The trajectory plans must not cause any collisions with the robot itself • The robot should implement a local trajectory plan to reach target points by avoiding obstacles. • Robot joint angles data available • Robot tool center point coordinates and speed available • Information about the robot tool state (on or off), the program lines, where a product/part must be gripped and robot input output signals available • In the simulation environment; The robotic system must not respond to any external remote-control command or condition that causes a hazardous situation.	UC1_INO_TR_6, UC1_INO_TR_7	Inovasyon

	• The servo motor is operated at the user-defined speed and direction • The motor speed and direction can be set by the remote-control application		

2.1.3. UC3 – ALBERO's Use Case (Spain)

The main objective of the MUWO project is the development of an Integrated Manufacturing Platform to offer intelligent automation of flexible production in companies. To do so, this project has to maximise the operating margin, process performance or minimising production costs by optimising the manufacturing processes.

This main objective has been divided into the following sub-objectives:

Table 3. Application scenario requirements and related technical requirements for Use-case 3 (Spain)

Application Scenario Requirement ID	Application Scenario Requirements	Related Technical Requirement	Partner
UC3-SR_1	Creation of APIs to communicate the information from the databases to the systems that make up Muwo.	UC4_ACCURO_ES_2 UC3_ACCURO_ES_3	ACCURO
UC3-SR_2	Development of artificial intelligence algorithms with the aim of analysing and understanding the information being processed.	UC4_ACCURO_ES_4 UC4_ACCURO_ES_5	ACCURO
UC3-SR_3	Process planner, by creating an AI-based variant generator that can use a basic description of the manual process to create several production alternatives.	UC4_ACCURO_ES_5	ACCURO

UC3-SR_4	Combine processes from different production lines in real time.	UC4_ACCURO_ES_5	ACCURO
UC3-SR_5	Determine production rate, production batch size and production sequence when production rate, set-up cost and unit processing cost are sequence dependent.	UC4_ACCURO_ES_5	ACCURO

2.2. Application Architecture and interfaces

2.2.1. UC1 - IDEPA's Use Case (Portugal)

Portuguese consortium conjoint efforts have developed the architecture presented in Figure 3, specifying the components in each block and overall interfaces, with the final goal of integration in MUWO CLOUD platform. In this use case the following components are considered:

- Data Platform – sensors from the machines will be constantly sending data to a Smart Box;
- Equipment Health Monitoring System – this component will be responsible for data visualization (real time and historic), trigger alerts to the users in case of abnormal values or events proceeding from the predictive maintenance algorithms;
- Autonomous Action Broker – this component will allow the definition of flexible workflows for notification and automated control of software and hardware interfaces;
- Industry Data Relay – this component aggregates several heterogeneous data flows from the production environment to power upper layers of functionality (ex. Algorithms, EHMS);
- Scheduling Algorithm – this component will be responsible for scheduling / rescheduling algorithms;
- Predictive Maintenance Algorithm – this component will be responsible for predicting equipment failures and provide warnings;
- Quality Prediction Algorithm – this component will be responsible for predicting the product quality.

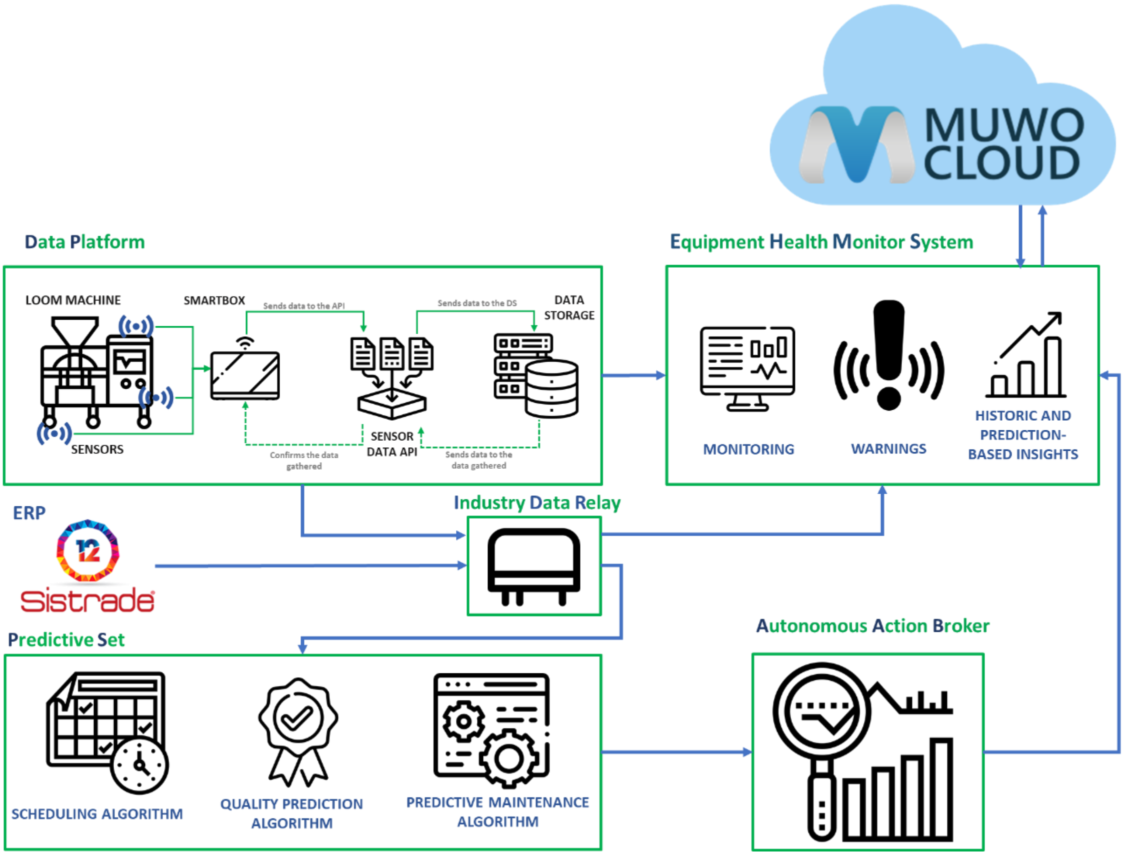

Figure 3 – Portuguese use case System Architecture

In Figure 4 it is shown the flow diagram for the Portuguese use case. It is shown the procedures taken into each module and the decisions that are made in order to achieve an improved production line.

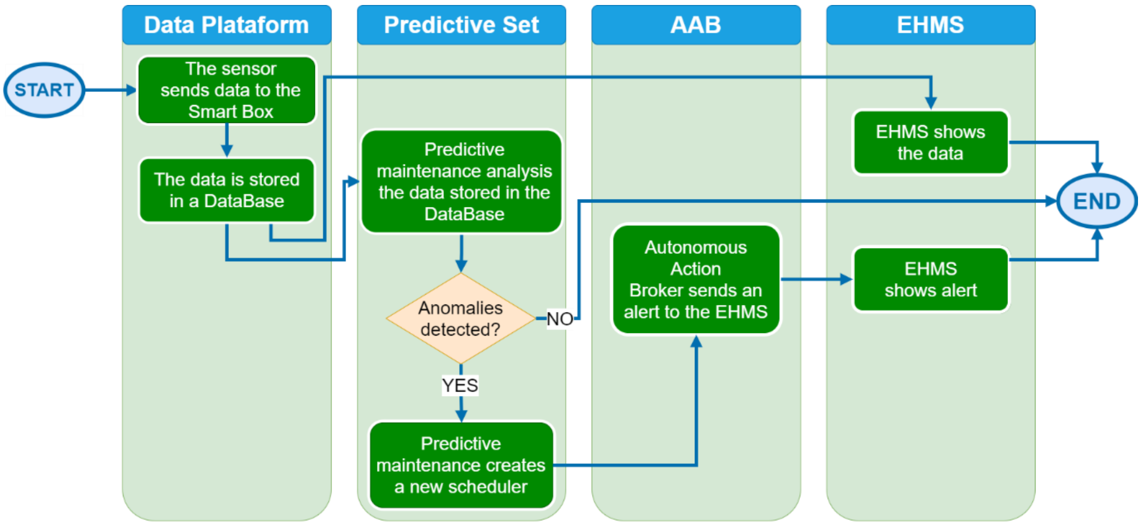

Figure 4 – Portuguese use case flow diagram

2.2.2. UC2 - GTF Rotor Cell Operation (Turkey)

For the second use case of the MUWO project. UC contributors have specified common system architecture for the initial stage plan. In System architecture created based on Alpata's use case (Figure 4), given architecture plan supports different interfaces and components. In use case scenario, various adapters are planned to be connected to the sensor layer and through middleware integration, data acquisition, data interpolation and classification will be done for MUWO platform. In planned architecture, Decision support system and Artificial Algorithms (AI) play important role for the platform, In decision of the production processes, AI and simulations are important with decision support system integrations. With analysis of real and simulation data, process variants are tested and suitable production models are planned to be created.

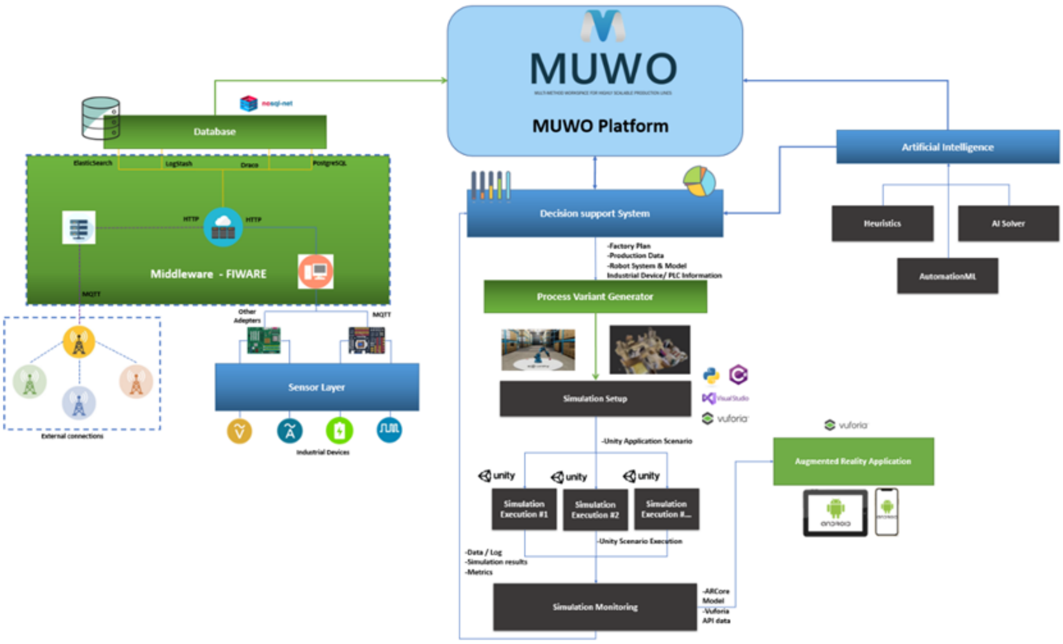

Figure 5. Turkish Use Case System Architecture

The workflow diagram of the Alpata use case is given in Figure 5. In workflow diagram, overall process for material processing is explained. For the gicen use case, process flow for autonomous system with robotic units is aimed to be simulated in virtual environment for different production environment variants and find suitable process model for given production aims. In figure 6, description of interfaces and connection of equipments and interfaces between different actions are provided. Also, activities as well as information flow are visualized.

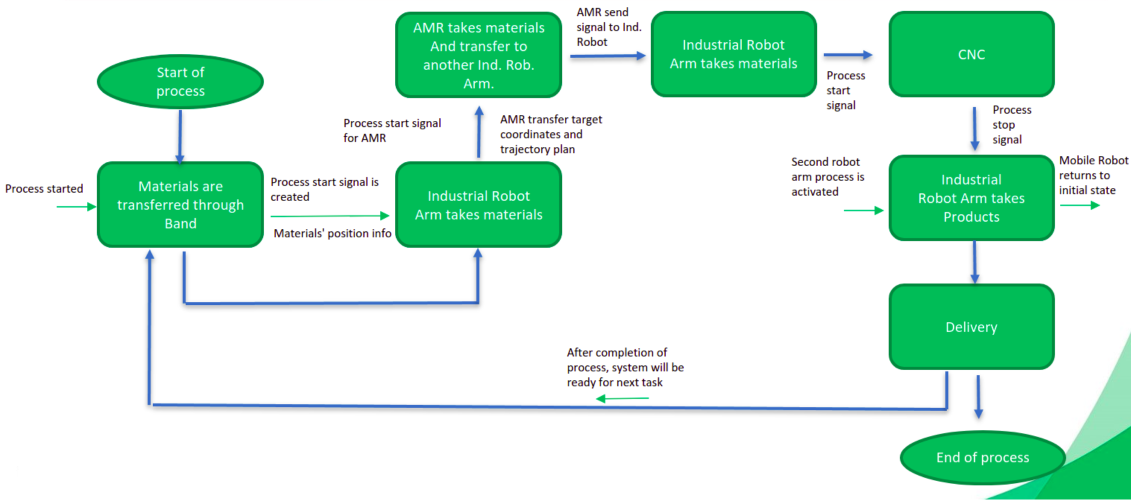

Figure 6. Workflow diagram

2.2.3. UC3 – ALBERO's Use Case (Spain)

For Albero use case, Spanish consortium has developed the architecture presented in Figure 7, in which the components forming it have been grouped in different blocks.

In the first block, there will be a Gateway that collects information from the sensors that make up the system to later store the data in a cloud server, which will also have the computational load of the system.

1. The second block consist of the artificial intelligence modules. The module will be a Q-learning based algorithm in which the information collected by the sensors is analyzed in search of anomalies and in order to study the performance of machines and factory operators. This information will be correlated by means of artificial intelligence algorithms with the ERP information in the Production Planning module in order to improve production planning.
2. In the third block, a knowledge database which will store the final results obtained after applying the Q-learning and artificial intelligence algorithms will be developed.
3. In the last block, an API communication will be established. This API will give access to the information of the databases, both the one containing the gateway information and the knowledge database.

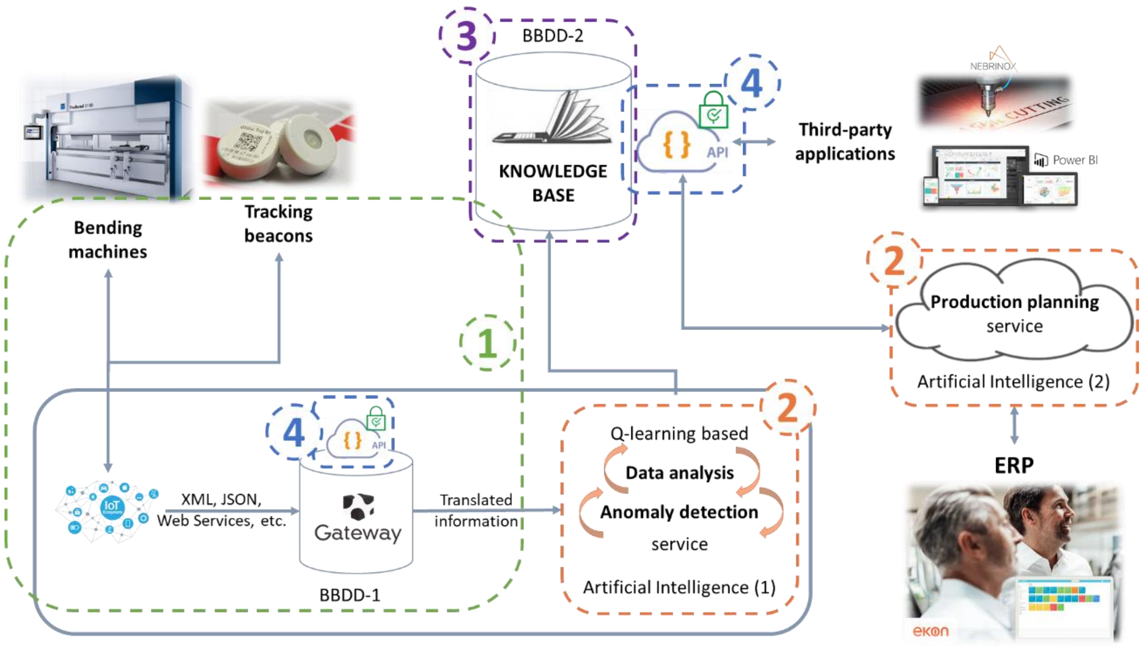

Figure 7. Spanish use case System architecture

The artificial intelligence algorithm that will be applied in Muwo can be seen in Figure 8. The tasks it performs are as follows:

- Data from the ERP system will be collected and work orders, workers and available materials will be assigned in order to issue the work orders in the most efficient order; this is, give an optimized production plan.
- The results obtained will be stored in the database once the assigned manufacturing process is finished when the machine is turned off.
- To finally place the order, this information will generate a balance of results of the workers involved in the process.

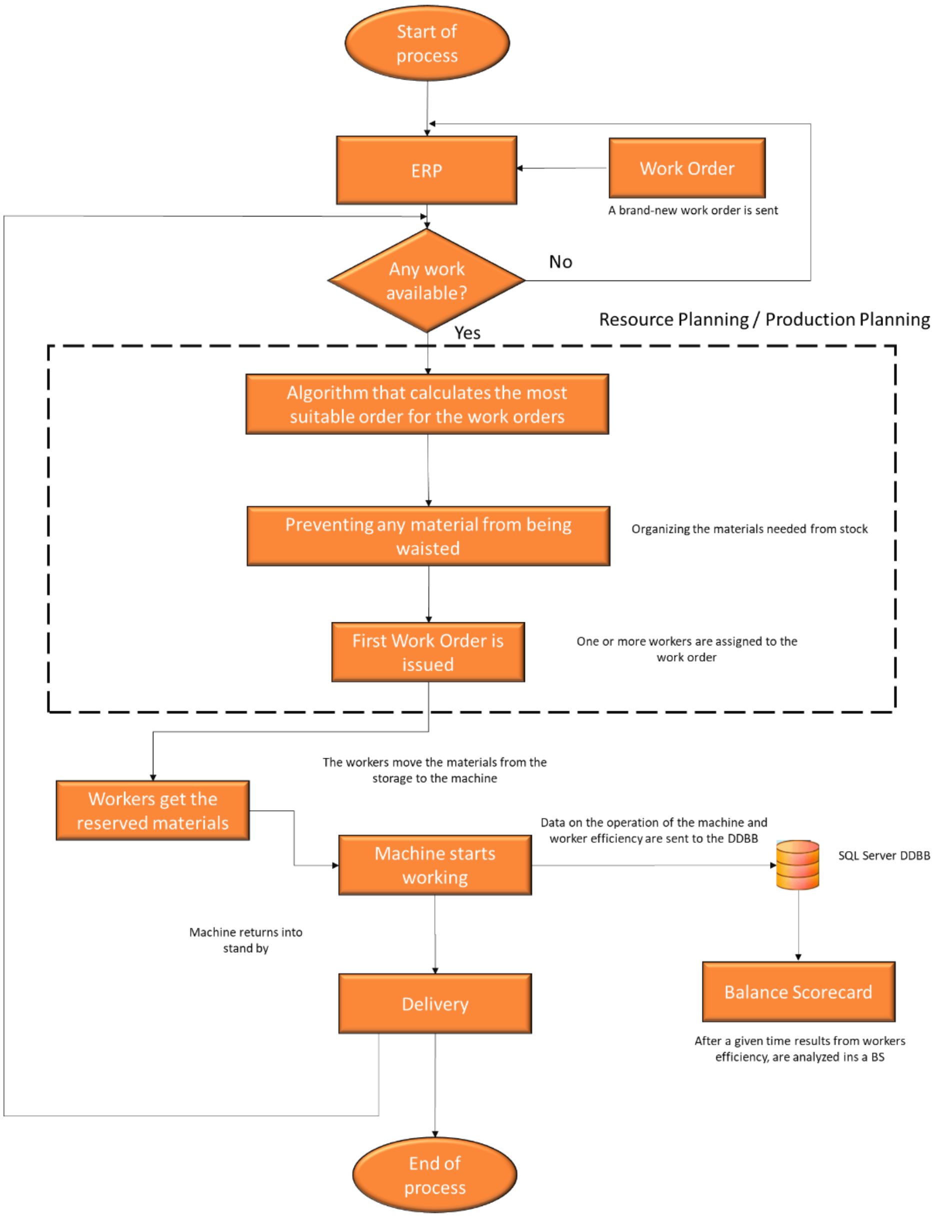

Figure 8. Spanish use case workflow diagram

2.3. Connected Equipments

2.3.1. UC1 IDEPA's Use Case (Portugal)

For the Portuguese use case, the following sequence (Figure 1) is used, as described in section 2.1.1. Distinct types of information are gathered from the different types of sensors applied to the looms. This data will create a basis for the development of intelligent algorithms. In each loom machine the following parameters are measured:

- Rotation speed (RPM) – This will indicate the speed that principal motor is spinning
- Motor temperature – This sensor will indicate the electric motor functioning temperature, which will be associated with the rotation speed and workload;
- Distance produced – This will measure the length of produced material;

- Air humidity – Humidity levels are constantly measured.

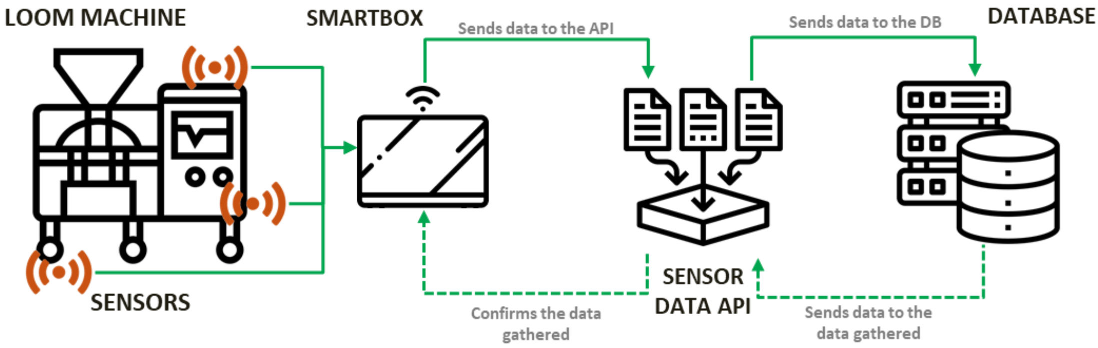

Figure 9 – Portuguese use case data collection sequence

2.3.2. UC2 - GTF Rotor Cell Operation (Turkey)

The operation within the scope of this simulation scenario (Figure 10. Industrial Process Workload

);

- Putting the parts coming on the band to the AMR by a robot arm positioned in front of this band,
- AMR delivers this part to another robot arm positioned between CNC and Delivery,
- This is the production of the robot arm in CNC with the delivered part.
- Finally, the robot arm in front of the CNC will deliver the part to the Delivery section when the production is completed.

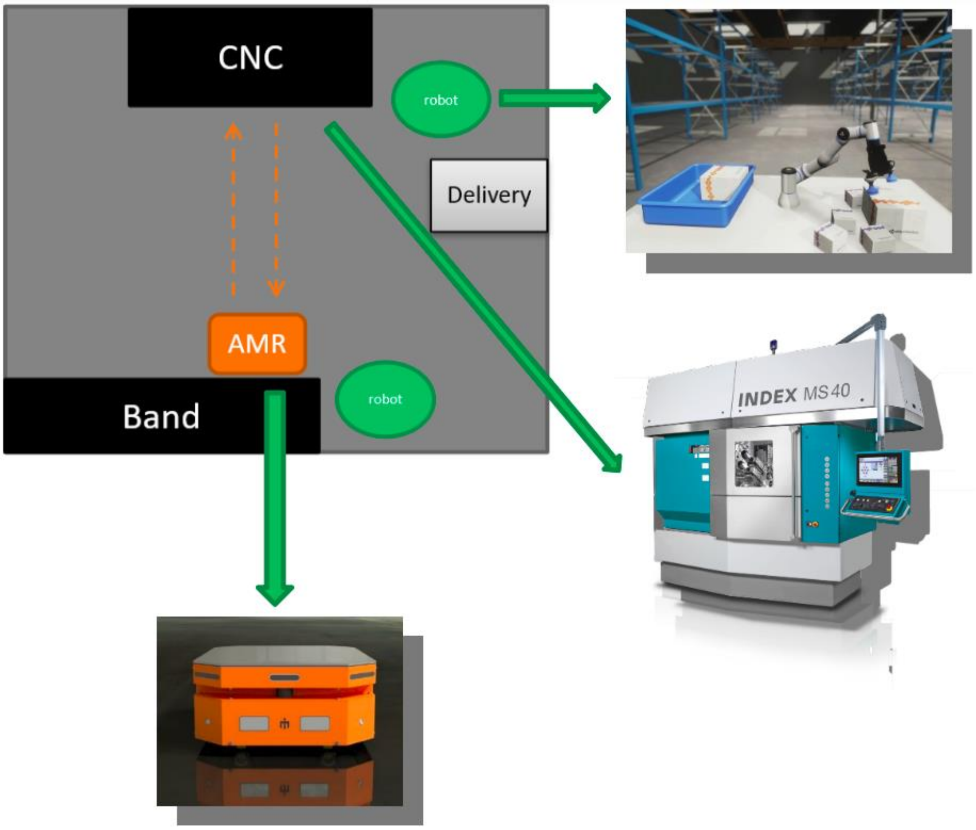

Figure 10. Industrial Process Workload

2.3.3. UC3 – ALBERO's Use Case (Spain)

The data to be used by the Spanish consortium for subsequent analysis with artificial intelligence are as follows:

To collect the information from the factory, a database will be created that will collect the information through a gateway.

- Collection of information from the bending machines.
- Collecting information from the tracking beacons.

On the other hand, data will be collected from the company's ERP. This information will be analysed together with the results obtained after analysing the information from the factory, as shown in Figure 11.

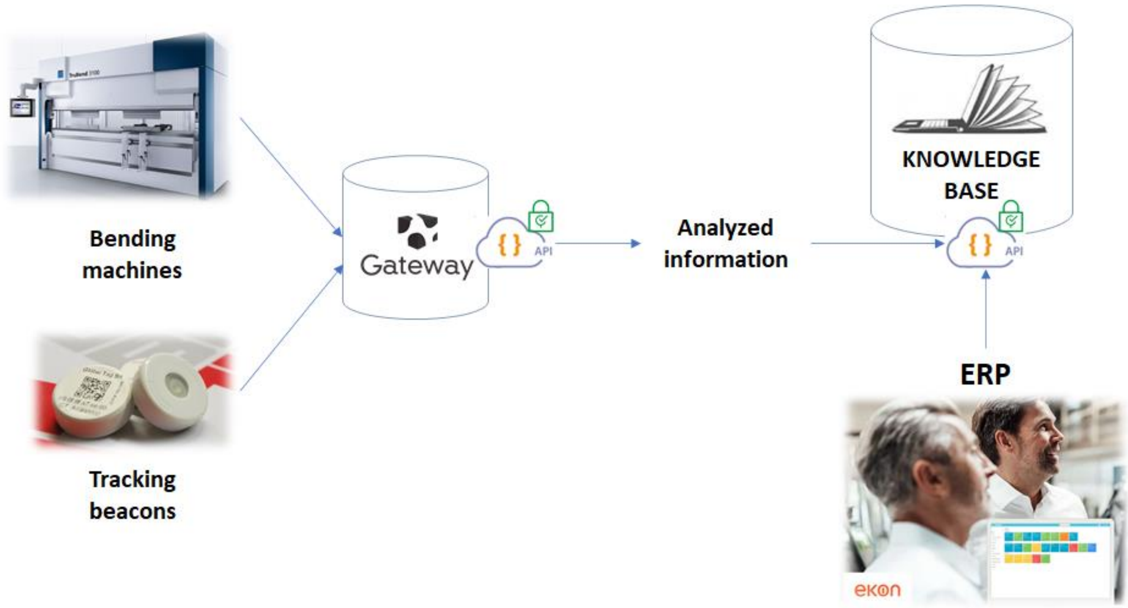

Figure 11. Gathering of information for the use case

2.4. Interfaces

2.4.1. UC1 - IDEPA's Use Case (Portugal)

Component A	Component B	Technology	Protocol	Data Exchanged
Sensor	Smart Box		IO-Link	This collects the data from IO-Link devices at the field level and forwards them to a higher-level system such as the Smart Box
Smart Box	Sensor Metrics Handler	OPC Server	OPC UA	It transfers the data to the API via OPC UA
Sensor Metrics Handler	Data Base	Webservice	TCP IP	The data received by the Sensor Metrics Handler is stored in a data base
Data Base	Access Data Middleware	Webservice	HTTPS	A set of procedures is

Component A	Component B	Technology	Protocol	Data Exchanged
				performed to retrieve the data from the data base
Access Data Middleware	EHMS	Webservice	HTTPS	This API will send the requested information, in the form of a JSON Object, to the EHMS via HTTPS
Access Data Middleware	Predictive Maintenance	Webservice	HTTPS & MQTT	This API will also send encrypted messages, every 5 seconds, with sensor data, in the form of a JSON Object, to the Predictive Maintenance.
Predictive Maintenance	Smart Interlayer Data Distributer	Webservice	HTTPS	This API will send the predictions data, in the form of a JSON Object, to the Smart Interlayer Data Distributer.
Smart Interlayer Data Distributer	EHMS	Webservice	HTTPS	This API forwards the JSON Object to the EHMS
Smart Interlayer Data Distributer	Autonomous Action Broker	Webservice	HTTPS	This API will forward the data from the

Component A	Component B	Technology	Protocol	Data Exchanged
				Predictive Maintenance, rescheduling for example, in the form of a JSON Object, to the Autonomous Action Broker
Autonomous Action Broker	EHMS	Webservice	HTTPS	The Autonomous Action Broker will send the alerts, in the form of a JSON Object, to the EHMS

2.4.2. UC2 - GTF Rotor Cell Operation (Turkey)

Tools and software to be used within the scope of the project:

Component A	Component B	Technology	Protocol	Data Exchanged
Physic Engine	Unity	Firmware	Multiple	Physic models and control mechanisms interact with simulation environment and provide monitoring metrics for industrial process
Designer	Visual Studio		C#, JSON, Python	In Unity, where the simulation environment will be designed, the necessary software to run the robot models will be

Component A	Component B	Technology	Protocol	Data Exchanged
				created with the help of Visual Studio.
AR Technology	Vuforia Engine	Application	ARCore, ARkit	Supporting the simulation environment to be developed with augmented reality will be realized with the Vuforia Engine tool. With this tool, the simulation environment designed in Unity will gain AR support. The AR plugin to be created can be used on Android and IOS phones and tablets.
Robot	AMR	Physical Asset		robot that can understand environment and move through in it without being controlled directly by an operator. Typically, this is achieved through volumetric sensors, sophisticated on-board sensors, computers, and maps, which allow AMRs to understand and

Component A	Component B	Technology	Protocol	Data Exchanged
				interpret their environment.
Robot	Industrial Robot	Physical Asset		Robotic arms are generally utilized in picking, packing, sorting, and a variety of other applications. Paired with other technologies, these arms can dramatically reduce effort and cost in industrial operations.
Sensor	Data Acquisition Devices		HTTP, MQTT, FiROS, CANBus…	In operation environment, there are various types of information being requested from process floor. Environmental data, human and machine information is important for creating transmutable simulations for different processes. In use case scenario, data acquisition devices enable obtaining information from industrial robots, AMRs, CNC

Component A	Component B	Technology	Protocol	Data Exchanged
				machines and other factory assets.
Middleware	FIWARE		HTTP,NGSI10,STH API	Middleware is known as a software that provides services and applications outside of operating system's offerings. Middleware services are important for messaging authentication, management and cloud computing systems. For application scenario, FIWARE middleware provides data acquisition from devices with different software interfaces. This enables data transfer from low level to high level systems in reliable way.
Decision Support	Scheduling Algorithms	Software		Making the data (preparation time, processing time, transportation time between machines, energy consumed, etc.) available in

Component A	Component B	Technology	Protocol	Data Exchanged
				planning/scheduling algorithms with the help of a model based on the product/part collected as big data, estimation of parameters in similar operations for personalized products, Development of real-time scheduling process taking into account production dynamics

2.4.3. UC3 – ALBERO's Use Case (Spain)

Communication interfaces:

Both beacons and folding machines will send data to the API Gateway, which will be responsible for storing the information in the database. Visual Studio will be used to develop the APIs.

The first API developed will collect the information in JSON, Web Service or XML format and will be stored in a SQL Server database.

Data output	Data Entry	Communication format	Data processing
Beacons	API Gateway	Send bytes over bluetooth 5.1	Sending information from the beacons to the API.
Bending machines	API Gateway	---	Sending information from the Bending machines to the API

Data output	Data Entry	Communication format	Data processing
API Gateway	Database Gateway	SQL query	Sending the data collected by the API to the database.

Subsequently the information from this database will be collected from the API Gateway to be analyzed in the artificial intelligence system. The results obtained will then be sent to another API which will be responsible for storing the information in the knowledge database.

Data output	Data Entry	Communication format	Data processing
Database Gateway	API Gateway	SQL query	Sending data from the database to the API.
API Gateway	Artificial intelligence Q-learning	Web Service, XML y JSON	API request to obtain the data to be analyzed.
Artificial intelligence Q-learning	API Knowledge	Web Service, XML y JSON	Sending the results obtained from the analyzed information to the knowledge API.
API Knowledge	Database Knowledge	SQL query	Sending the information from the API to the knowledge database.

The results obtained after applying the Q-learning algorithm will be analyzed together with the information received from the ERP and these results will be stored in the knowledge database. Finally, these results will be displayed in a web application with different graphical elements such as charts and KPIs.

Data output	Data Entry	Communication format	Data processing
Database Knowledge	API Knowledge	SQL query	Sending the information from the database to the API.
API Knowledge	Inteligencia artificial Algoritmo de planificación	Web Service, XML y JSON	API request to obtain the data to be analyzed.
Inteligencia artificial Algoritmo de planificación	API Knowledge	Web Service, XML y JSON	Sending the results obtained from the analyzed information to the knowledge API.
API Knowledge	Database Knowledge	SQL query	Sending the information from the API to the knowledge database.
Database Knowledge	API Knowledge	SQL query	Sending data from the knowledge database to the API.
API Knowledge	Interfaz web	Web Service, XML y JSON	Sending information from the knowledge API to the web application.

3. Conclusion & Further Plans

In the Objective of creating MUWO platform, besides overall image of the project architecture, interfaces and connection of modules are important part of MUWO project. In this Deliverable, application scenarios of each use cases, overall use case structure plan and planned process workflows are introduced. This information is then used for explaining Application architectures and interfaces of the project. For each use case, connected equipment are shown in a common standard and interfaces are explained for future integration and demonstration purposes.