General approach to describe processes

Deliverable 4.1

MUWO

MULTI-METHOD WORKSPACE FOR HIGHLY SCALABLE PRODUCTION LINES

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Abstract	In order to allow the modification of a production line, it must be possible to decide whether a two different production means can be used for the same process or not. For this, an appropriate description should be defined.
Keywords	Process, workflow, production time.

Function	Name	Entity
Author	Ali Kafalı	ACD
Editors	Mustafa Karaca	Inovasyon
	Irene Torrego	Accuro
Contributors	Ricardo Martins Filipe Correia Fábio Coelho André Oliveira	Sistrade
	Irene Torrego	Accuro
	Ali Kafali	ACD
	Mustafa Karaca	Inovasyon
	Murat Saglam	Alpata

Executive summary

The objective of the WP4 is to simulate single production cells. Such a cell may contain different production means and must be able to handle a certain process. Simulation of the intended process, it must be possible to derive further simulations, i.e., the simulation of the same process with other production means, and the simulation of another process with the given production means. In this aim, D4.1 In order to enable a change in production systems and the generation of new process alternatives, a unified process description is given in D4.1 with detailed process descriptions and process workflows.

Partner contributions record

#	Entity	Contributor on Phase 1	Date of Contribution1	Contributor on Phase 2	Date of Contribution2
1	Accuro	X	30/05/2022		
2	ACD	X	27/05/2022		
3	Alpata	X	01/06//2022		
4	Evosoft				
5	Inovasyon	X	27/05/2022		
6	ISEP	X	27/05/2022		
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Changes record

Version	Date	Entity	Description of Changes
V0.1	27/04/2022	ACD	Creation of the document structure and UC2 information.
V0.2	27/04/2022	ISEP, Sistrade	Added information related to UC1 in sections 2.1 and 3.1.
V0.3	30/05/2022	Accuro	Added information related to ALBERO’s use case in sections 2.3 and 3.3.
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V1.1	01/06/2022	Alpata	Added information related to GTf Rotor Cell use case.
V1.2	06/06/2022	Accuro	Final review and editing.

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1. Introduction

1.1. Document objectives and scope

Smart hardware interfaces including both electrical and hardware interfaces will be defined.

In order to allow the modification of a production line, it must be possible to decide whether a two different production means can be used for the same process or not. For this, an appropriate description should be defined.

1.2. Document structure

In this document, Section 2 describes the processes involved in each of the use cases that will be improved with MUWO, the current situation of these processes. Then, the process workflows and accessibility of hardware for programming is defined in Section 3. Lastly, Conclusion and plans for future deliverables are explained in Section 4.

2. Description of Processes

In workflow systems, Process is known as representation of a process in computer environment including manual and workflow definitions. The definition of Process includes all important information about the processes which present itself for workflow enactment softwares to be executed. The information includes starting and completion conditions, activities, context and rules to navigate between activities. In this term, run-time control functions behave as a connector between the process definition and the process as it is in real life world.

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

Idepa is a textile manufacturing company producing textile fine fittings with more than 50 years of history. The company is making its way to the Industry 4.0 paradigm, implementing a digitization pilot program for its legacy equipment's, as seen in Figure 1. As part of its ambition to deliver high quality products to its customers, it aims to leverage the data acquired from four industrial legacy looms retrofitted with the latest digital sensors, edge processing technologies and protocols. The production facility of IDEPA is comprised of several sections:

Commercial, this section is responsible for the management of human resources and commercial issues;

- Warehouse, IDEPA has two warehouses, one is responsible for the weft of big reels that will be used by the Jacquard and Ratière looms;
- Jacquard, this section comprises a park of dozens of jacquards looms;
- Ratière, this section comprises a park of dozens of ratière looms;
- Cutting and finishing, this section is responsible for product finishing and cutting;
- Dyeing, this section is responsible for the painting and inking of the products, as well as ironing;

- Planning, this section is responsible for planning all aspects of shop floor operation (ex. Production scheduling);
- CAD Design, this section handles the product design;
- Screen/Offset Printing, this section is responsible for printing paper tags and films.

Figure 1. IDEPA evolution timeline

The company is now producing a great amount of bottom-up data, most of it acquired by the Sistrade ERP and it will be providing the data as a testbed base for the MUWO technologies, although machine data is not collected. For better quality of products and to reduce machine downtimes, it is only logical to collect this data, analyse it and predict failures in quality and machines, so rescheduling can be made to diminish the cost and time lost.

IDEPA has two independent production processes:

- Manufacture by Jacquard type looms
- Manufacture by Ratiere type looms

Current IDEPA Production System > Jacquard

The flow of the Jacquard production process is summarized in the following diagram:

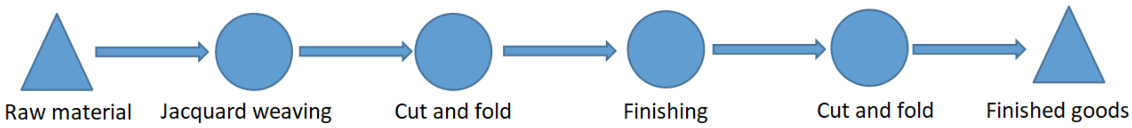

Figure 2. Jacquard production process

In this process, the yarns are acquired abroad and supply the production for long periods (typically 3 months). The reel is of medium or heavy height and size. The orders and respective planning are not dynamically very high. In addition, the equipment is capable of providing a large number of variables about the production process.

Current IDEPA Production System > Ratière

The Ratière production process flow is summarized in the following diagram:

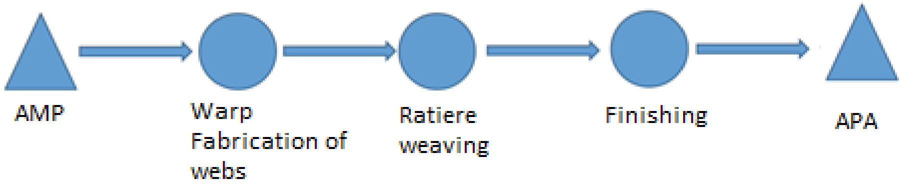

Figure 3. Ratiere production process

In this process, the yarns are purchased abroad and supply the production for long periods (typically 3 months). The reel is of medium or heavy height and size.

- Three warping machines, two old-fashioned and one more recent
- The webs are of reduced size and weight. Each web has the capacity to supply a loom for a relatively short period.
- There are six distinct loom classes. Within each class, non-homogeneous functional group, the looms are distinguished by the maximum width that can work.
- Each loom has several heads (six), and only one or all of them can be in operation at the same time.
- The physical characteristics of the yarn greatly influence the permissible weaving speed, which can vary by a ratio of 1 to 10 times
- There are high dynamics in terms of orders, as well as marked seasonality

IDEPAs use case has a SmartBox (a Programmable Automation Controller (PAC)), connected to four industrial loom machines, acting as an edge-layer connector between the loom's sensors and actuators, and the information systems. Data exchange between the Smartbox and the partner entities (Sistrade and ISEP), is done through the MQTT streaming protocol.

This data is stored in the data lake so that it can both be used to train the machine learning algorithms and be accessed by the EHMS platform. From the ISEP side, this data will be fed into the machine learning algorithms, which in turn will send an alert to the EHMS platform in case of quality or machine failure. These machine learning algorithms will help determine the condition of in-service equipment in order to estimate when maintenance should be performed (predictive maintenance algorithm). They will also provide valuable feedback on the outcome of the manufactured products (predictive quality algorithm), allowing the worker to better understand the issues with the equipment or what he can do to produce better products. The algorithms can also reschedule the manufacturing order in case of machine failure (scheduling algorithm).

From the Sistrade side, this data will be presented in the EHMS platform. The EHMS platform contains widgets that will allow the user, to check the sensor values in real-time and allow him to manually configure the alert values, allowing the platform to dispute alerts. One of the most important aspects of the EHMS platform will be the possibility for the user to visualise data either in real-time or historical. EHMS provides the possibility to swap between these two visualization modes, allowing a highly flexible analysis and data display to the user, according to his needs. These functionalities are critical in the EHMS compared to the stateof-the-art tools in the market, since they allow a deep analysis of the collected data, providing the user with visual feedback on the data variation.

Finally, the user can also send feedback to the machine learning platform, for instance, incoming incorrect warnings, allowing the algorithms to retrain based on this feedback and consequently providing more accurate information in the future. This bidirectional data flow enhances the decision-making process.

2.2. UC2 - GTF Rotor Cell Operation (Turkey)

In GTF Rotor Cell Operation use case, there are smart industrial resources to be planned in production cell. The production cell, which consists of components such as CNC, robot arm and conveyor described in the previous sections in the factory environment, has been designed to be naturally positioned in the middle of the factory. After the robot model was added to the factory environment, models of other production components began to be added. Conveyor belts, which will enable the transport of the parts to be processed in the system, were also drawn through the Blender program and added to the Unity environment. Models for CNC machine and robots are designed with according to real life systems. In Production Cell scenario:

1. A production cell that creates the digital twin environment; It consists of two robot arms, conveyor belts that carry the products to be sent and to come, a CNC machine, a transport robot and a human operator inspecting the incoming products.
2. The robot arms in the production cells that make up the digital twin environment (simulation environment for short) must meet the requirements specified in UC2_SR_1.
3. The production processes to be carried out in the simulation environment should be determined by the inputs to be sent from outside.
4. The operations performed at that moment in the simulation environment should be displayed on an information panel in the simulation environment.

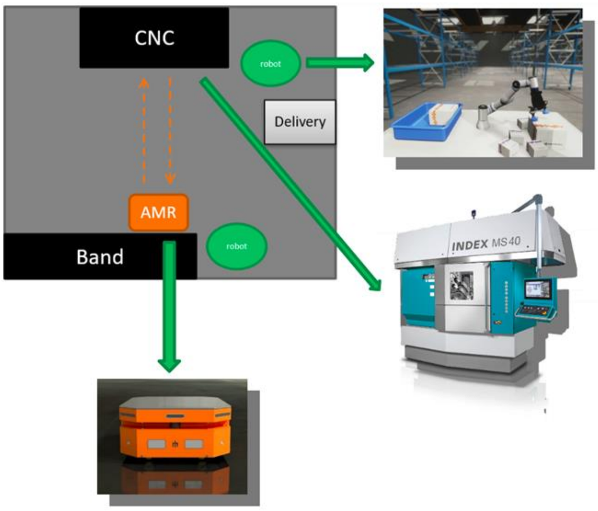

Figure 4. GTF rotor cell production means

2.3. UC3 - ALBERO's Use Case (Spain)

The processes that are carried out in ALBERO cover different areas in the transformation of metal, from the cutting of metal parts of different materials and thicknesses, to the assembly of components for different industrial sectors, including welding, punching or bending of the material. The process of metal transformation include:

- **Laser cutting** of different materials and thicknesses.
- **Punching** of iron, stainless steel, galvanised, aluminium, brass and copper with numerically controlled punching machines.
- **Bending** with tools adapted to the needs of the component.
- **Welding**, both manually with operators specialised in MIT, TIG and spot welding and with robotised MIG welding cells.
- **Deburring**, **polishing**, edge rounding, removal of scale, satin finishing, brushing and grinding of metal surfaces.
- Baked EPOXI powder **painting**.
- **Assembly** of components for different industrial sectors.

The manufacturing process of the metallic components begins with the cutting and punching of the metal sheets, as illustrated in Figure 5, processes which are carried out in parallel according to the specifications of the parts to be produced.

They then move on to the bending stage, which accounts for 80% of the average production time, making it one of the main bottlenecks in the production of lift components.

The parts then go to welding, where they are welded together to form larger components.

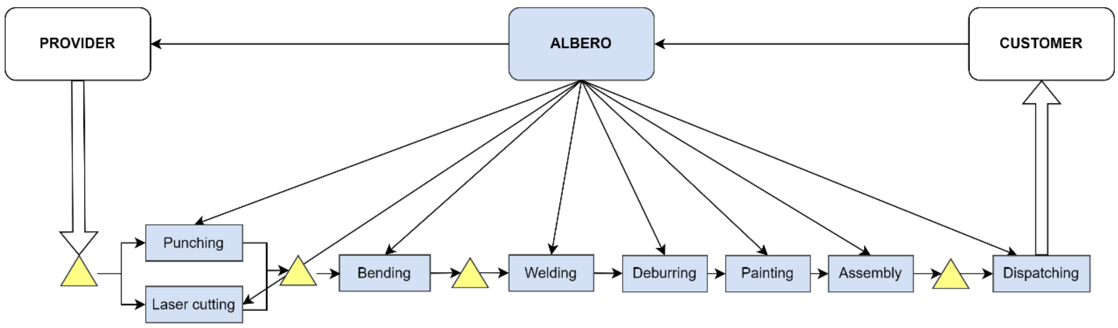

Figure 5. Workflow in ALBERO

Finally, the parts undergo deburring and painting, if necessary, before reaching the assembly area, where the assembly of lift, hoist or garage doors is carried out.

Much of the production workload lies in the cutting phase, as it is the first phase of production and all parts go through it. In particular, the laser cutting operation is the one with the heaviest workload: approximately 95% of the parts start the production cycle here. This is why production planning is currently based on the work capacity of these machines, the availability for the rest of the phases and the type of material to be used, in the following order:

1. Delivery date to the next stage and without falling outside the delivery deadline.

2. Material qualities: steel, stainless steel, aluminium, etc.
3. Material thickness: from 0.8 to 20 mm.
4. Format (to optimise batch production of highly repetitive parts and large quantities): 3000 x 1500, 2500 x 1250, etc.

Once the parts to be manufactured have been grouped according to this criterion, part placement software is used to make the best use of the material. This algorithm created by TRUMPF - manufacturers of machines for metal transformation - uses a technique known as nesting, which allows the distribution of the parts to be cut on a sheet (2D) of metal of the indicated size to be planned, as illustrated in Figure 6, reducing the free space between parts to a minimum so that waste is as small as possible and, if large gaps remain unused, they can be used in the next round of cutting.

To speed up the laser cutting process, the workers create a "wheel" of material in which sheets of different materials and thicknesses are arranged continuously, as in a wheel, and fed into the machine gradually. When the parts for one material have been cut, the next material is fed in and so on until the wheel is finished, then the first material and thickness is started again.

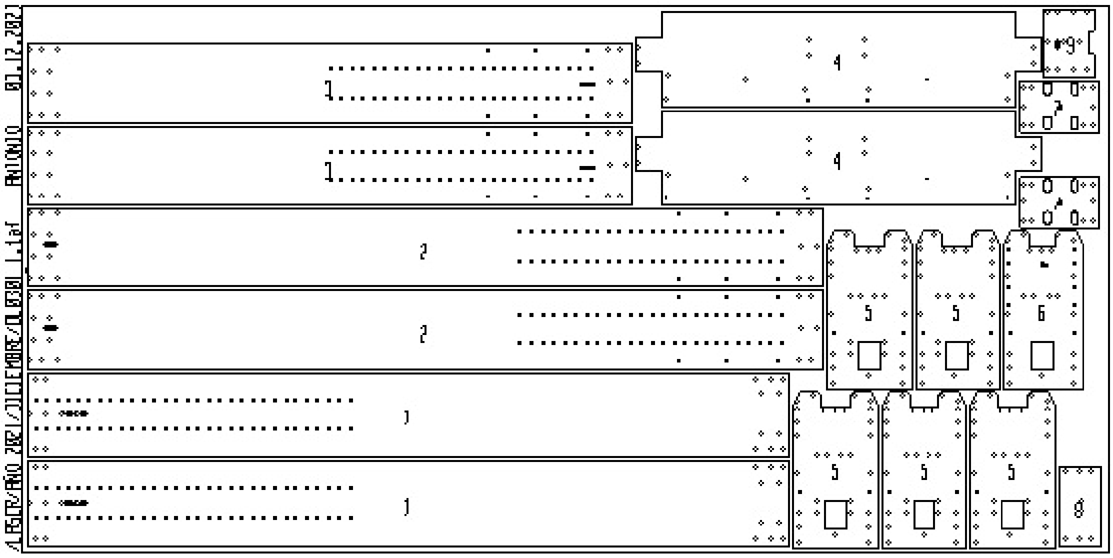

Figure 6. Laser cutter preparation plan through automated nesting

3. Process Workflows

3.1. UC1 - IDEPA’s Use Case (Portugal)

The IDEPA use case is a complex system, with multiple components involved and with a constant data flow. Most of the components to be developed, such as the EHMS, are highly data-dependent, making it critical to correctly establish the system architecture and type of data/format that will be exchanged.

To better illustrate the system, a sequence diagram was created (Figure 7).

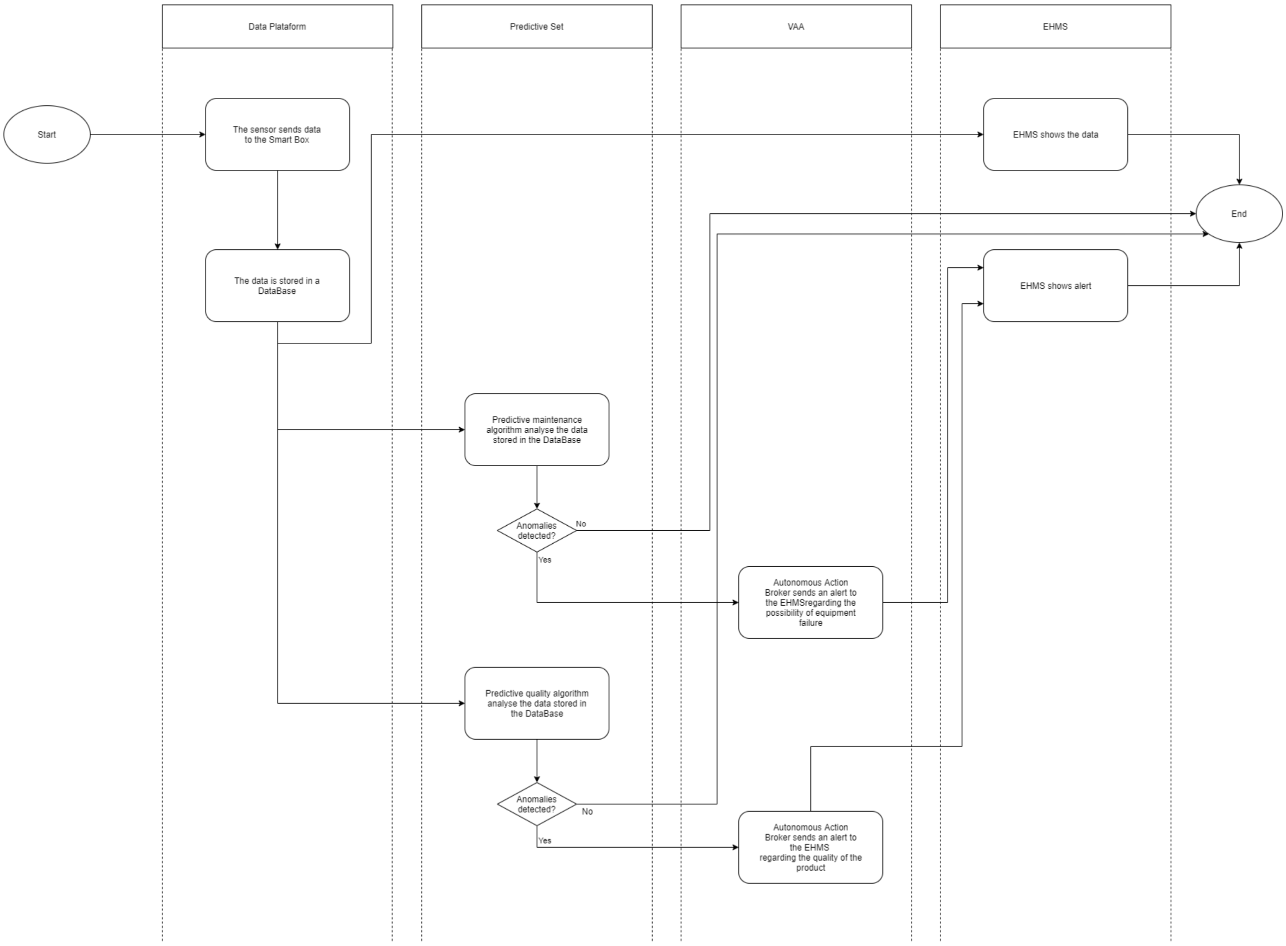

Figure 7. EHMS Sequence Diagram

As Figure 7 illustrates, the SmartBox acquires the data provided by the sensors. This data is then stored in MongoDB that can be accessed by Sistrade EHMS or the predictive algorithms elaborated by ISEP and Sistrade. These algorithms will analyse the data and if anomalies are detected these anomalies will be analysed. If it is a quality anomaly the quality algorithm will trigger a quality alarm in the EHMS. If it is an equipment anomaly, the predictive maintenance algorithm will trigger a maintenance alarm in the EHMS. These alarms allow the user to better understand "what is happening" because visual feedback is very important to comprehend how the EHMS platform works.

3.2. UC2 - GTF Rotor Cell Operation (Turkey)

Reading the production data from the factory production plan, transferring the parts to be produced by making machine capacity planning to the virtual cell, finding the optimum production result according to different variations in the virtual cell and transferring it to the real production cell are the steps of the project.

In production area, cutting tools will transfer by automatic guided vehicle (AGV).

For Each CNC machines, the cutting tools will load into the machine by a robotic hand.

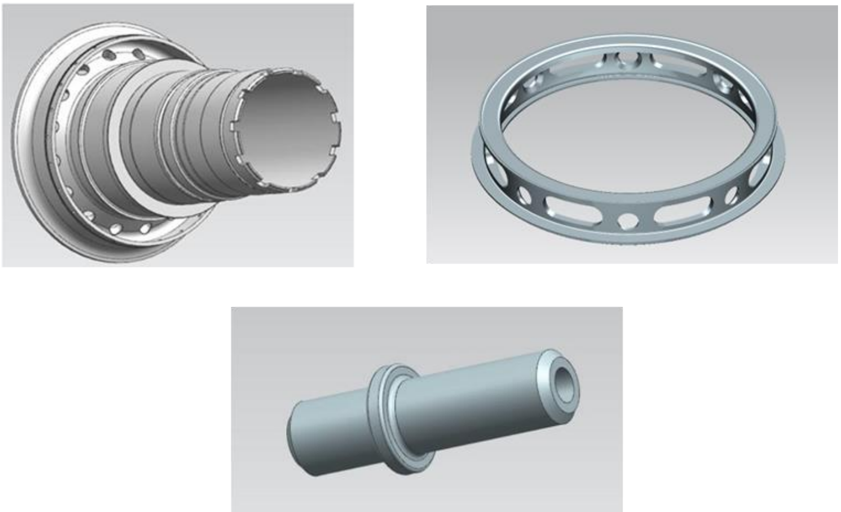

Figure 8.Cutting tools

Figure 9. CNC cutting machine

Figure 10. Automated guided vehicle (AGV)

Table 1. List of parts to be produced, production time broken down into different phases (operation, part loading/unloading, tool loading/unloading), monthly sales and number of machines that can be used at the same time to produce them

Part number	Operation number	Operation duration time (min)	Set-up time (min)	Part loading / unloading (min)	Tool loading / unloading (min)	Sales for per month	Number of using tool (1 set)	Number of machines that can be used at the same time (due to fixtures constraint)
XXX1461	100	30	30	10	7	13	7	1
XXX0009	200	102	30	10	16	35	16	1
XXX0009	400	422	30	10	33	35	33	2
XXX1236	300	90	5	10	13	19	13	1
XXX1865	100	14	5	10	2	18	2	1
XXX9801	200	119	15	10	16	70	16	1
XXX9801	500	490	15	10	23	70	23	2
XXX6217	400	352	20	10	16	15	16	2
XXX1865	200	114	9	10	9	18	9	1
XXX1385	350	44	60	10	3	12	3	1
XXX9801	3600	15	20	10	1	70	1	1
XXX9801	400	270	20	10	17	70	17	1
XXX0986	110	53	45	10	3	12	3	1
XXX6217	300	132	15	10	7	15	7	1
XXX0970	210	38	60	10	2	11	2	1
XXX6217	1500	20	15	10	1	15	1	1
XXX0986	310	40	30	10	2	12	2	1
XXX1865	400	243	12	10	12	18	12	1
XXX6217	200	186	15	10	9	15	9	1
XXX1865	450	62	7	10	3	18	3	1
XXX9801	300	105	15	10	5	70	5	1
XXX0986	210	127	100	10	6	12	6	1

XXX0009	300	132	20	10	6	35	6	1
XXX0970	510	22	30	10	1	11	1	1
XXX1385	475	23	60	10	1	12	1	1
XXX0986	335	23	60	10	1	12	1	1
XXX9801	600	100	15	10	4	70	4	1
XXX0970	310	151	100	10	6	11	6	1
XXX0970	410	51	30	10	2	11	2	1
XXX1865	300	292	13	10	8	18	8	1
XXX0009	500	600	15	10	5	35	5	2
XXX6217	500	367	17	10	3	15	3	2
XXX0009	600	108	15	10	1	35	1	1

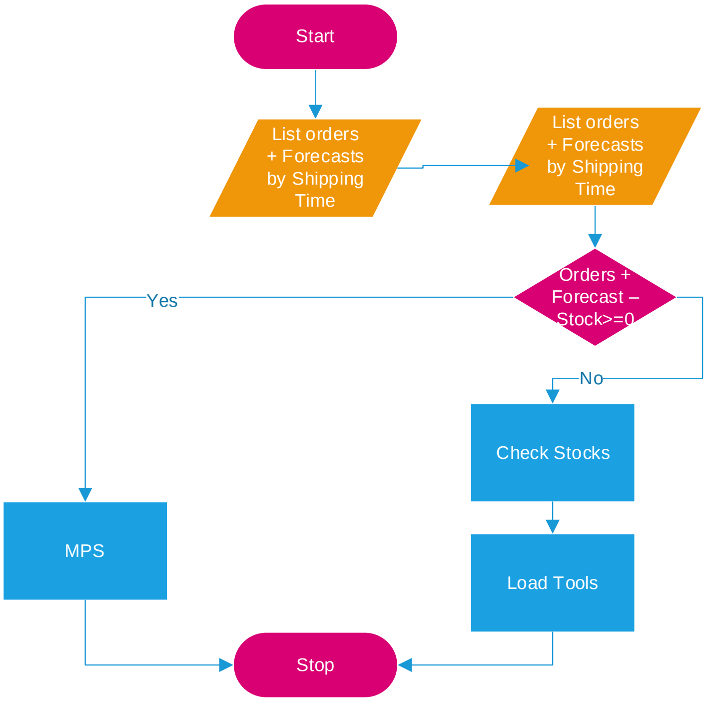

Figure 11. UC2 process workflow

Table 2. Front production parameters

MPS Parameter Name	**Front Production Parameter**
Description:	The purpose of the pre-production parameter is based on the product code of the products. it is necessary to determine how many weeks it can be produced in advance. When defining the production parameter from the front, identification will be made on the basis of the product code
Step #1:	A single parameter will be defined for a product code
Step #2:	Parameter identification is performed by entering the max week information
Step #3:	The pre-production parameter defined for the product means that no more than the number of weeks defined at the planning stage can be pre-produced.

Table 3. Product priority parameters

MPS Parameter Name	**Product Priority Parameter (strategic)**
Description	The strategic product priority parameter will be defined. Parameter identification will be made on the basis of the product code.

MPS Parameter Name	Product Priority Parameter (strategic)
Step #1	The parameter will be defined as 1,2,3, etc.
Step #2	The product with a small parameter value has the highest priority
Step #3	It will be defined weekly.

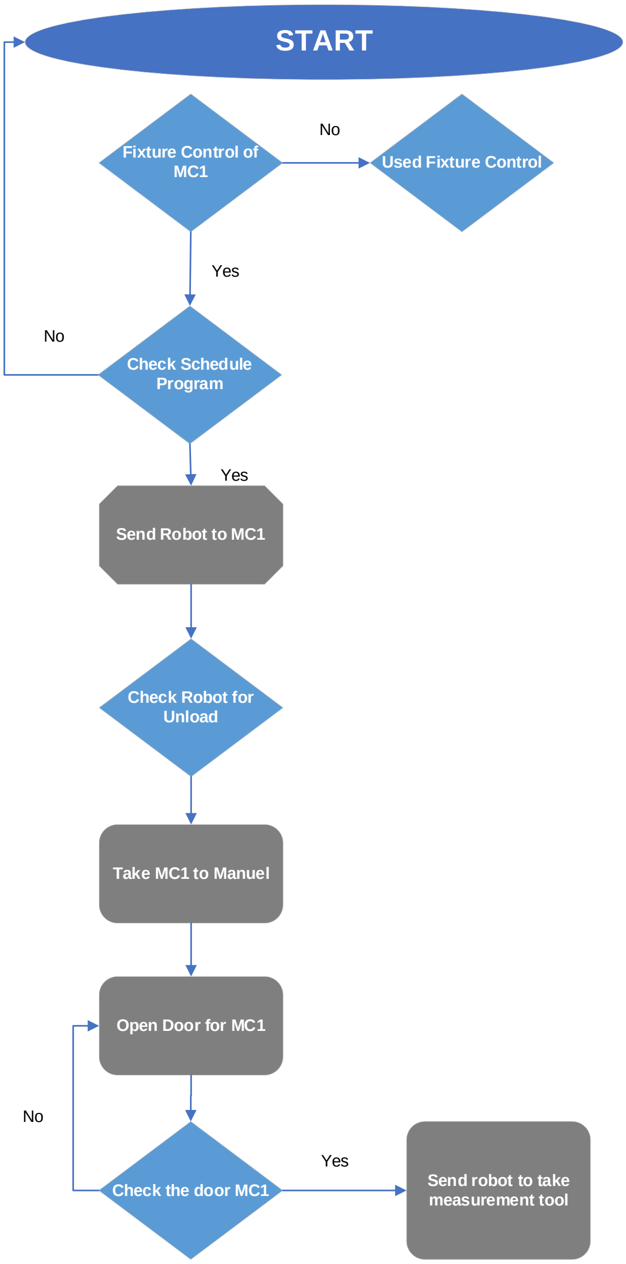

Figure 12. Robot operation process

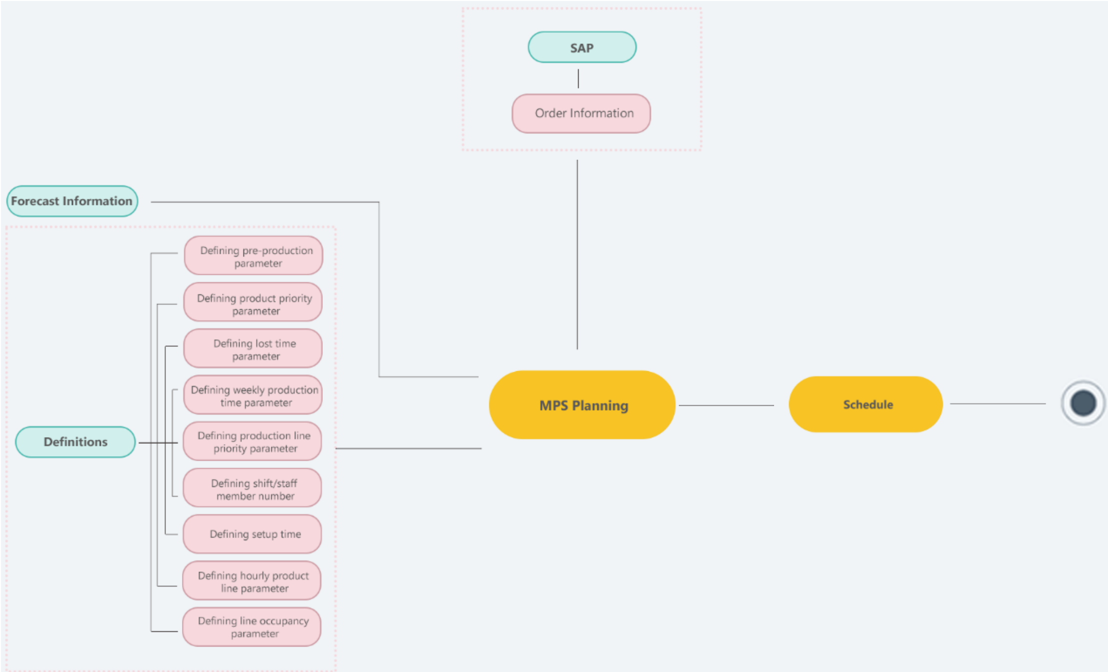

Figure 13. Data flow

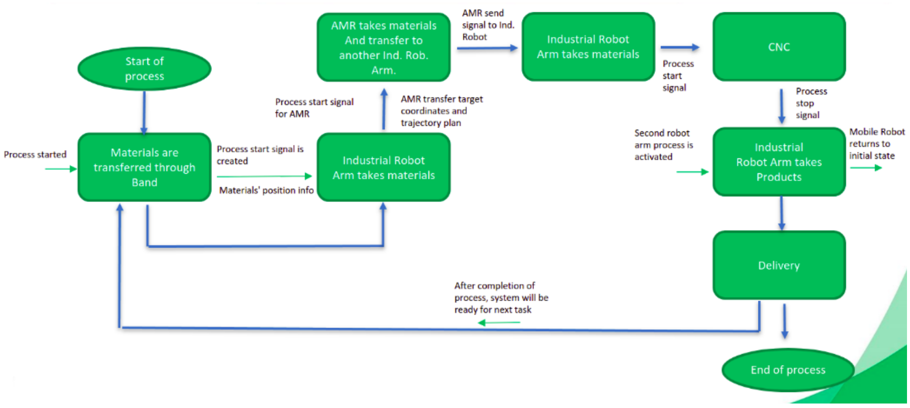

Figure 14. Connected Equipment GTF rotor cell

3.3. UC3 - ALBERO's Use Case (Spain)

Part of the development of this use case consists of the development of an algorithm for production planning, taking into account points 1 to 4 described above. In order to know where exactly the algorithm should operate and to understand the process, the production planning workflow shown in Figure 15 has been designed.

The process starts with checking the available work in the ERP, according to the orders coming from the "Sales" module. If no work is available then the manufacturing process is put on hold. When available work orders are found, then the planning algorithm starts to work, estimating the optimal order of work orders taking into account:

1. Product delivery deadline.
2. Material qualities to be used.
3. Material thickness to be used.

4. Material format.

After calculating the appropriate order, the work orders are sent to the nesting software with an automated configuration to optimise material utilisation. Once this is done, the work orders are issued and the workers can pick up the required material from the warehouses and feed it into the machines. When the machines have finished the cutting process, the parts are sent to the next stage of production, which will depend on the type of part to be produced.

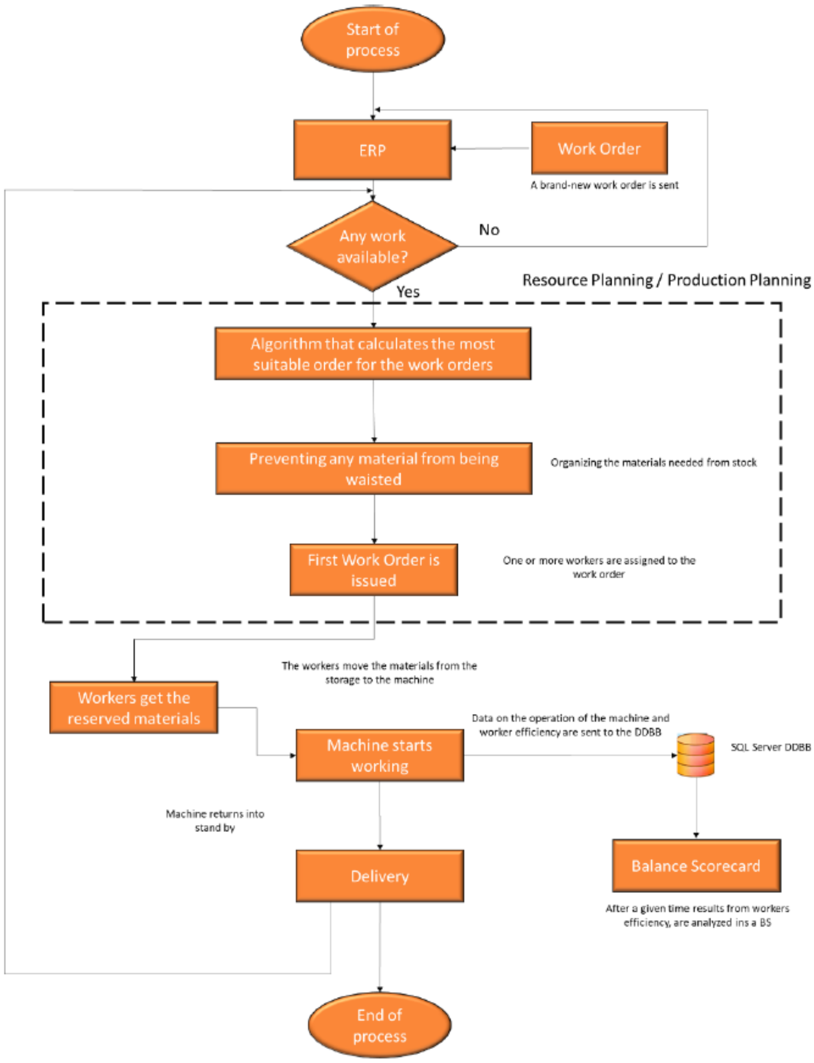

Figure 15. UC3 workflow diagram

While the operators use the machines, data is collected from them in relation to usage time, production frequency, faults, etc. as well as data related to the performance of the workers (average production times by component type, breaks, machine being used, etc.). This information is represented in dashboards and indicators that make it easy to understand and make decisions based on them.

Furthermore, the analysis of the production data collected is used to feed back into the production planning algorithm in terms of production times for each part, and machine and worker availability and capacity.

This process is constantly in operation so that production does not stagnate at any point, always taking into account work and rest times to avoid having to work overtime.

4. Conclusion & Future Plans

In this document, the description of Smart hardware and production means have provided. In first chapter, Document objectives and relation of the A In third chapter, the connection of the production means is given with connected equipment and interfaces. In last chapter, the process and programmability is described through given use case architectures. In next Deliverables, the description of software components and interfaces will be given in detail.