NARRATE

Regenerative Resilient Smart Manufacturing Networks

D5.1 Pilot planning report - Early pilot demonstrator (a)

2025/06/09

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D5.1 PILOT PLANNING REPORT - EARLY PILOT DEMONSTRATOR (A)

Work package	WP5
Task	T5.1
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Deliverable lead	AIDIMME
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Abstract	This deliverable describes the planning for the early pilot demonstrator, indicating its scope through the requirements coverage and the defined KPIs, presenting the involved technical solutions with the overall architecture, describing the activities carried out for the preparation of the demonstrator, and presenting the tentative evaluation and validation schedule.
Keywords	Pilot planning, Pilot use cases, User stories' mapping, KPIs, Pilot evaluation, Pilot validation, Execution plan

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DOCUMENT REVISION HISTORY

Version	Date	Description of change	List of contributor(s)
0.1	2024/10/03	Definition of preliminary Table of Contents	AID
0.2	2025/04/10	Minor adjustments in document structure	AID
0.3	2025/04/16	Addition of disruption resilience	BUL
0.4	2025/04/24	Addition of smart advisors' solutions	PL
0.5	2025/04/29	Addition of Automated Workflows & Production Process Orchestration	FhG
0.6	2025/05/12	Introductions by NUNSYS and re-structuring of technical chapter	AID, NUN
0.7	2025/05/19	Addition of KPI analysis	MED, AID, FhG/BUD
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1.0	2025/06/09	Last revision by coordinator	AID

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STATEMENT ON MAINSTREAMING GENDER

The NARRATE consortium is committed to including gender and intersectionality as a transversal aspect in the project's activities. In line with EU guidelines and objectives, all partners – including the authors of this deliverable – recognise the importance of advancing gender analysis and sex-disaggregated data collection in the development of scientific research. Therefore, we commit to paying particular attention to including, monitoring, and periodically evaluating the participation of different genders in all activities developed within the project, including workshops, webinars and events but also surveys, interviews and research, in general. While applying a non-binary approach to data collection and promoting the participation of all genders in the activities, the partners will periodically reflect and inform about the limitations of their approach. Through an iterative learning process, they commit to plan and implement strategies that maximise the inclusion of more intersectional perspectives in their activities.

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The NARRATE Consortium is the following:

Participant number	Participant organisation name	Short name	Country
1	INSTITUTO TECNOLOGICO METALMECANICO, MUEBLE, MADERA, EMBALAJE Y AFINES-AIDIMME	AID	ES
2	SCIENTIFIC ACADEMY FOR SERVICE TECHNOLOGY EV	SERV	DE
3	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV	FhG	DE
4	INSTITUT NATIONAL DES SCIENCES APPLIQUEES DE LYON	INSA	FR
4.1	INSAVALOR SA	INSA-V	FR
5	SOFTWARE AG	SAG	DE
6	F6S NETWORK IRELAND LIMITED	F6S	IE
7	SYNESIS-SOCIETA CONSORTILE A RESPONSABILITA LIMITATA	SYN	IT
8	MEDWOOD SL	MED	ES
9	DHL EXEL SUPPLY CHAIN SPAIN SL	DHL	ES
10	NUNSYS SA	NUN	ES
11	BUDATEC GMBH	BUD	DE
12	BRUNEL UNIVERSITY LONDON	BUL	UK
13	POLICY LAB	PL	EE
14	BLUEBRIDGE SOLUTIONS UG	BLU	DE
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Abbreviations

AI	Artificial Intelligence
AM	Additive Manufacturing
BB	Building Block
CEP	Complex Event Processing
CF	Carbon Footprint
DED	Deliverable Expectation Document
DSS	Decision Support System
DT	Digital Twin
DTPL	Digital Twin Processing Language
EC	European Commission
ERP	Enterprise Resource Planning
IMC	Intelligent Manufacturing Custodian
JIT	Just-In-Time
KPI	Key Performance Indicator
LLM	Large Language Model
MaaS	Manufacturing as a Service
MES	Manufacturing Execution System
MSx	Milestone x
Mx	Month x
NSDSS	Neuro-Symbolic Decision Support System
NSQA	Neuro-Symbolic Question Answering
OEE	Overall Equipment Effectiveness
PDMM	Pilot Digital Maturity Model
QA	Quality Assurance
RFP	Request For Proposal
RTM	Requirement Traceability Matrix
SCOR	Supply Chain Operations Reference model
SMN	Smart Manufacturing Network

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SC	Supply Chain
TC	Test Case
Tx.x	Task x.x
UAT	User Acceptance Testing
UC	Use Case
VOCs	Volatile Organic Compounds
UR	User Requirement
US	User Story
WP	Work Package

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EXECUTIVE SUMMARY

The purpose of this Deliverable is the analysis of three different pilots (furniture production, multi-sector 3D printing and semiconductor manufacturing) with the final goal of enhancing manufacturing agility and supply chain resilience. This pilot analysis is conducted through two main activities. On the one hand, the requirements collected from the pilots' users based on user stories are revisited and prioritized according to the particular needs and expectations of each pilot. This prioritization provides a clearer picture of the aims of the industrial partners, which is a valuable resource at any moment during the implementation and deployment phases. On the other hand, the identification of specific KPIs for each pilot case corroborates the expectations from the users and enables the measurement of the impact produced by NARRATE in the pilot real environments and particular industrial ecosystems. The results of the requirements prioritization and the analysis of KPIs support the selection of main requirements, also considering the scope of NARRATE and the required alignment to the Manufacturing-As-A-Service topic, enhancing the supply chain resilience in response to unexpected disruptions taking into account the environmental aspects on any decision within manufacturing ecosystems.

The last part of this report is focused on the definition of the criteria for pilot validation, and the proposal of a plan for the deployment and execution of the NARRATE technological solutions. For validation criteria, the aim is to provide handy mechanisms to perform an optimal analysis of the offered functionalities to determine the proper fulfilment of requirements. The suggested validation process included the definition and execution of test cases and the adoption of the Requirement Traceability Matrix to determine the scope of application of the available functionalities, and how they are expected to be operated. At the same time, the recommended traceability approach enables both pilot users and developers to keep on track of the status of the expected functionalities and the corresponding validation process following the Pilot Digital Maturity Model in NARRATE helping assess the level of technological advancement in the pilots and guide them toward higher levels of digital integration and innovation. Updates, adjustments, and fixes can be reported to keep all the partners involved on track and act accordingly. The deployment and execution plan introduced in this report - which will be refined and more detailed in future activities - is the basis for the scheduling of the software releases to be realized during the project, as well as the corresponding testing and validations from the pilots' side.

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1. INTRODUCTION

1.1. PURPOSE AND SCOPE

The purpose of deliverable D5.1 Pilot Planning Report - Early Pilot Demonstrator (a) is to report the tentative planning for the early pilot demonstrator containing all the activities carried out in the scope of task T5.1.

The expected technical solutions are introduced to provide its scope of application and role in the overall proposed architecture. Moreover, the pilot requirements are revisited evaluating their alignment to the scope of NARRATE and the impact of the expected Building Blocks (BBs) in these requirements, to assess their effective appliance. A particular relationship between the defined KPIs and the requirements has been established to get a more comprehensive overview of the expected impact of the technical solutions on the proposed pilots.

The main overall output of this deliverable is the generation of a tentative workplan to guide the implementation of the early demonstrator, based on the technology roadmap. Therefore, its focus is the addressing of two main project objectives: O5.1 establishing the framework for the evaluation, validation and demonstration of the implemented solutions, and O5.2 defining the workplan for the evaluation and revisiting the metrics to be used for the pilot assessment.

It is worth noting that some relevant aspects directly related to this document have been discussed in the consortium General Assembly held by the end of May 2025, so a small delay in the submission was needed to provide more comprehensive and determining content in this report.

1.2. RELATIONS TO OTHER DELIVERABLES

The tasks reported in this deliverable D5.1 are mainly related to activities from WP1 and WP5. On the one hand, WP1 includes deliverables:

- D1.1 Project Requirements, which contains the pilot integrated requirements [1], and
- D1.2 Pilot Analysis [2] which contains the requirements' prioritization, the defined KPIs, and the proposal for the validation criteria to be followed in WP5.

On the other hand, all deliverables in WP5 are strongly related, therefore

- D5.2 Pilot Implementation – R2 with final release of modules,
- D5.3 Final pilot evaluation with final release of platform, and
- D5.4 Pilot planning report - early pilot demonstrator,

present the progression of the implementations and the corresponding demonstrators. This deliverable D5.1 can be considered as the basis for the other documents in the sequence, so it presents the tentative workplan as guideline for the execution of the pilot demonstrators. In this regard, it is also related to the deliverable

- D8.2 NARRATE technology roadmap [3]

since the proposed deployment plan is closely related to the digital technology roadmap included in such deliverable, that established the tasks, timing and milestones

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for defined phases. Moreover, the current report considers the overall technical architecture described in deliverables

- D1.3 Energy Efficiency & Circularity [4], and
- D1.4 Architectural Requirements [5],

being the last one delivered in parallel with this pilot planning report.

1.3. STRUCTURE OF THE DOCUMENT

Since the purpose of this report is to provide a comprehensive overview of the planned activities to prepare the early demonstrator, it introduces a concise overview of the three pilots considered in NARRATE, which mainly cover the supply chain (SC) resilience in different application scenarios with their corresponding particularities. Following this, the pilot's requirements are reviewed considering the coverage provided by the technical solutions. After this, the advances in the KPI monitoring are reported, providing a clear picture of what has been considered and indicating the expected mechanisms for their retrieval. The pilot planning for early demonstrator is then presented as a tentative workplan to achieve a ready-to-use demonstrator for future evaluation. The pilot preparation section, which follows the planning one, outlines the preliminary setup activities carried out to advance the availability of the demonstrator. Finally, some overall conclusions related to all the previous activities are included, bringing also a short foresight of the further evaluation actions.

2. PILOTS REMINDER

A short reminder of the NARRATE pilots is included in the sections below together with a concise description and their main expectations.

2.1. PILOT #1 - IMPROVING AUTOMATION & SUPPLY-CHAIN RESILIENCE IN THE FURNITURE INDUSTRY BY MEDWOOD

MEDWOOD leads the Spanish market as children furniture manufacturer, and it is in the fourth position among its competitors in the Europeans market. The current expansion of the company in the production of polishing and melanin and logistics aspects involves the participation of DHL in the proposed pilot, given the actual limited digitalization of the supply chain management. MED needs to become more resilient facing challenges related to delivery terms and disruptions, considering that the company manages a wide range of customers and providers.

Even minor adjustments in the SC of the company (due to supply delays or demand updates) require a significant effort and time, given the limited communication facilities available in the SC.

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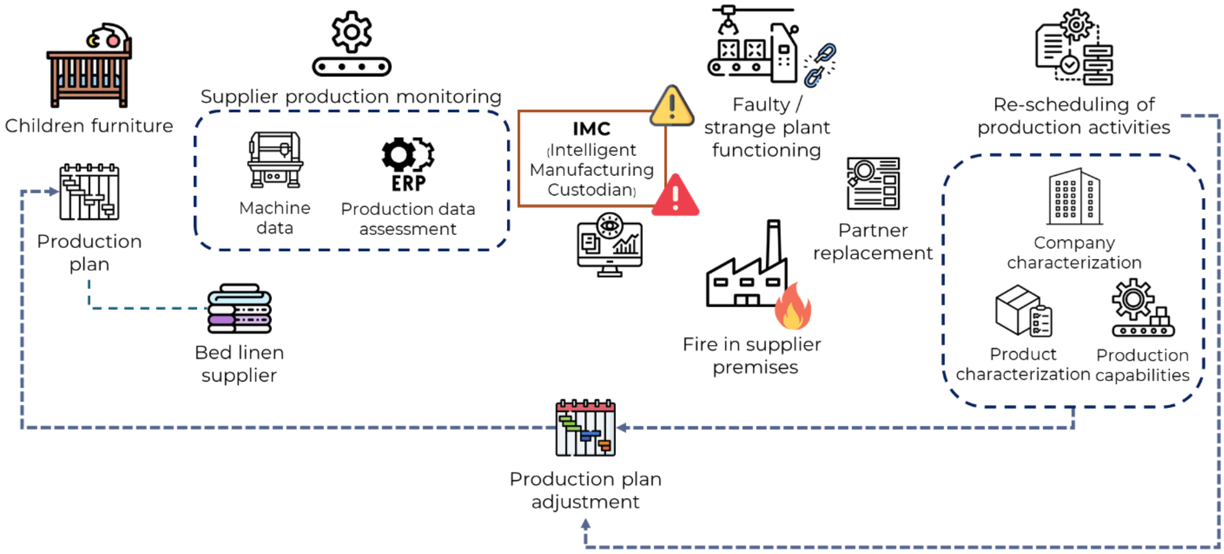

Figure 1: Workflow of the furniture pilot

Consequently, the MED pilot aims at addressing two aspects: the optional tracking of suppliers to gain awareness of potential anomalies that may affect the SC performance, and the finding of alternative production partners when critical deliveries are not available. In this regard, the availability of historical data may potentially increase the efficiency of such process.

2.2. PILOT #2 - PRINTING NETWORK AS-A-SERVICE TO IMPROVE RESILIENCE & MITIGATE UNEXPECTED DISRUPTIONS BY AIDIMME

The focus of the pilot led by AIDIMME is on additive manufacturing technologies. This basically starts with order management through the appearance of specific disruptions (e.g., machines failures, deformations) due to the complexity of the process. The actual additive manufacturing approach is based on small batches in the same or different geometry in one single product step, while the new approach is based on the decentralization of the production in a 3D printing network for the customers to externalize the production.

Figure 2: 3D-printing business models including printing net in Europe

Not only the management of the own production equipment but the contracted one in the 3D printing network are expectations of the pilot, including improved mechanisms to face disruptions. This way, the production could be redirected following heterogeneous criteria.

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AID does not currently offer Manufacturing as a Service (MaaS) as such. Thus, the objective of this pilot is to establish nodes in the network to overcome critical situations, meet the deadlines and mitigate the negative impact on the customers.

2.3. PILOT #3 - ESTABLISHING A NEW RESILIENT SUPPLY CHAIN FOR BUDATEC

The industrial company BUDATEC GmbH implements hardware for automation systems, and for the proposed pilot considers topics related to the efficiency of the use of energy and resources in the scope of Industry 4.0, with an energy management demonstrator for the monitoring of the management of dynamic processes and the concept for flexible soldering production lines.

The company needs to decide on major strategic orders in a short term but with a long-term impact, so current orders and processes must be addressed while reacting to unexpected events. Those non-substitutable elements are delivered in up to one year, while the production design and the general shortage of supplied parts lead to a faulty manufacturing area so the production needs to be expanded to an additional location.

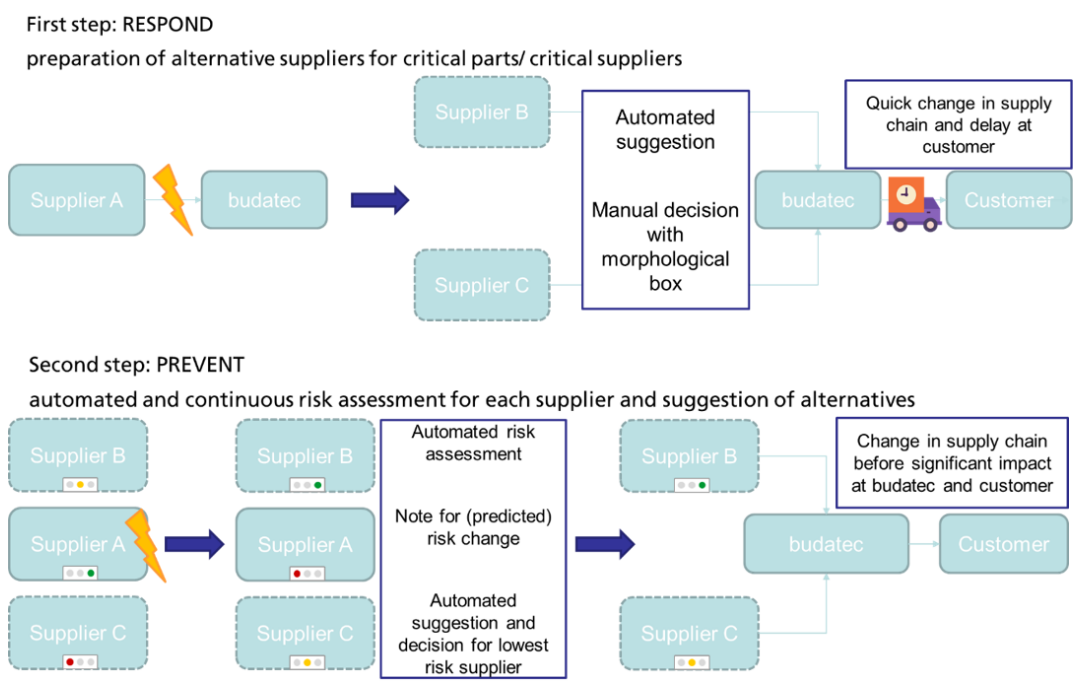

Figure 3: Workflow of the functionality expected from BUDATEC

Consequently, the pilot proposes a system for the anticipation to unforeseen events at the supplier side, proposing solutions for delivery problems (e.g., supplier replacement) and focusing on critical parts (e.g., non-substitutable components with a long delivery term).

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3. KPI'S FOR PROGRESS MONITORING

A further review of the KPIs defined for the three pilots was conducted. In this review, both pilot-specific and generic KPIs were considered. This has been basically a 'merging' process with the objective of eliminating duplicates and providing a clearer vision of the resources to measure the impact of the implemented solutions. To this end, a specific code was assigned to each indicator for better Identification, using the pilot code (MED, AID, BUD) followed by an incremental number.

3.1. PILOT-SPECIFIC KPIS

In this section, the KPIs specifically defined for each pilot are described indicating some details, such as how are they calculated, and available data sources to enable their measurement and monitoring.

3.1.1. MEDWOOD Pilot-Specific KPIs

In the case of MEDWOOD (MED), the raw list of KPIs included three indicators that can be directly mapped to generic ones. They are: (1) Improvement in identification of potential risks & disruptions, that can be mapped to GEN_K01, (2) Improvement of on-time delivery, that can be mapped to GEN_K03, and (3) Reduction of carbon footprint (CF), that can be mapped to GEN_K04. The resulting list of MEDWOOD KPIs is presented below:

KPI ID	KPI Name	Expected Value (~)
MED_K03	Improvement in stock reduction	5 - 10%
MED_K04	Increase in customer satisfaction (quality preservation/JIT delivery and information on environmental performance)	5 - 10%
MED_K05	Improved partner relationships (capabilities awareness, quality preservation/just-in-time delivery	5 - 10%
MED_K06	Implement at least 10-15% of environmental aspects considered as criteria in supplier assessment and selection	5 - 10%
MED_K07	Reduction of quality incidents, including order errors	20 - 25%

TABLE 1: LIST OF MEDWOOD'S PILOT KPIS

- **MED_K03- Improvement in stock reduction**
  The raw information to calculate this indicator is extracted from the company ERP, particularly the inventory section. The calculation is performed through the annual stock historical data which is gathered from Excel files extracted from the ERP.

  It should be noted that, considering that the stock reduction just depends on the company volume, also the value of obsolete material is expected to be measured.

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The inventory level (that can be measured in units or in cost) may depend on the volume of turnover (more orders involve more purchases of materials). The type of sold product also affects this parameter (a product with less materials and more labour time required produces a decrease in the inventory).

Therefore, it was decided to determine more precisely the scope of this indicator and add a new one related to obsolescence (MED_K08) which will be described later.

The improvement in stock rotation is related to the duration of the inventory consumption. This rotation measures how many times a stock has been sold and refilled in a time range (e.g., one year). An improvement of this indicator means a more efficient approach in the products' storage, avoiding unnecessary costs due to excess of stock or even product loss. This can be calculated from the ERP of the company.

- **MED_K04- Increase in customer satisfaction**
  Considering the wide scope of this indicator, this can be divided in two main areas.

  On the one hand, the main focus of this KPI is on the customer complaints, which can be obtained from tickets of material replenishment made to the customers. Actually, the received issues are exclusively attributable to MED.

  On the other hand, the customer may depend also on the on-time deliveries. However, this is already covered by the generic indicator GEN_K03 Improvement of the on-time delivery rate.

  Besides this, the environmental performance is being considered as an additional indicator, but this aspect still needs to be confirmed.

  It is worth noting that there are no specific customer satisfaction measurements being implemented so far, so a significant effort needs to be made in this regard.

- **MED_K05- Improved partner relationships**
  The information required for the calculation of this KPI is gathered from local sources (e.g., the on-time delivery from suppliers is available in the ERP), considering the obtention of the partner profile information from other sources. Actually, there is no registration related to the 'quality' of the suppliers of MED, so this data is not manageable.

  The ERP of MED generates an Excel sheet containing historical data related to all the completed orders delivered on time (the actual delivery time corresponds to the planned one).

  After a deep evaluation of this KPI, is has been detected that this can be covered through two parameters. On the one hand, the quality of the providers. On the other hand, the on-time delivery of these providers. Given that the first parameter cannot be a priori calculated, the actual focus is on the on-time delivery by the suppliers of MED.

- **MED_K06- Implement at least 10-15% of environmental aspects considered as criteria in supplier assessment and selection**
  The company manages some environmental information, such as VOCs (Volatile organic compounds) in chemical substances, and the chain of custody certification in wood material.

  Regarding the calculation, the company manages a checklist depending on the type of supplier (e.g., certifications, delivery terms, location, price range, quality, etc.).

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The consideration of environmental aspects regarding the selection of suppliers could be implemented, but the difficulty in addressing the indicator in terms of expected results should be emphasized. A template with information of the suppliers should be generated to do the selection. Some checking system to evaluate the compliance of criteria by the suppliers will be required.

- **MED_K07- Reduction of quality incidents, including order errors**
  The local Excel files handled by MED for the quality assessment cannot be used as they are now available. Therefore, the company is developing a standard template to manage this information.

  The incidences are being reported on an Excel sheet indicating the clients, since this information is not available in the ERP. The availability of this information through the number of quality reports elaborated is being considered. The document of internal quality registers just a small collection of clients, that could be extended.

- **MED_K08- Obsolescence reduction**
  The stock level should be reviewed from time to time (e.g., every three months) to identify and classify those 'obsolete' products. This information is saved in the ERP of the company.

3.1.2. AIDIMME Pilot-Specific KPIs

As far as the AIDIMME (AID) pilot is concerned, the KPIs list included two indicators related to the reduction of carbon footprint and energy consumption, both equivalent to the generic GEN_04. Therefore, the resulting list of AID KPIs is presented below:

KPI ID	KPI Name	Expected Value (~)
AID_K01	Reduction in low-cost AM parts	20 - 30%
AID_K03	Improvement in OEE	5 - 20%
AID_K04	Reduction of the production time	25 - 50%
AID_K05	Improvement against unwanted critical events that may happen on the 3D printing process	25 - 50%
AID_K08	Improvement of waste management generated by production processes and potential cost reduction	5%

TABLE 2: LIST OF AIDIMME'S PILOT KPIS

It should be noted that the KPI AID_K06 (Extension of product life span) has been so far discarded so AID cannot guarantee the access to information about the pieces already produced and delivered to the corresponding client.

The current situation of the KPIs of the AID pilot has been analysed from historical data gathered from Internal procedures.

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- **AID_K01- Reduction in low-cost AM Parts**
  The information related to this indicator refers to each 3D printing quotation that the company has provided in response to customer requests. Cost calculations currently consider factors such as part volume, bounding box dimensions, build height usage, and footprint percentage, among others.

  When post-processing is required, additional charges are applied to those specific items.

  All costs include labour, infrastructure, profit margin, outsourcing (if applicable), and other relevant inputs. The document (in Excel format) has been extracted from the current cost calculation Excel sheet being used to calculate and provide quotations.

- **AID_K03- Improvement in OEE**
  The Overall Equipment Effectiveness (OEE) has been calculated for a specific 3D printer, using automatically collected data. The machine considered by the moment - an HP Multi Jet Fusion (MJF) system - records information related to production batches, including successful print jobs, cancelled jobs, and error occurrences.

  The document compiles historical data spanning from 2020 to 2024. Unfortunately, data from other printers is not being collected by the moment, so this KPI is expected to be evaluated for this specific equipment. The document has been extracted from PRINTOS, a digital platform connected to the system of AID, which collects and stores data related from the entire 3D printing process (HP MJF).

- **AID_K04- Reduction of the production time**
  Data collected for this indicator includes historical records (2024–2025) related to production planning and production times for one of the 3D printers primarily dedicated to serial production.

  This document is completed jointly by the production planner and the machine technician responsible for organizing the build batches.

  This information enables the assessment of the current AS-IS situation regarding the production time of 3D-printed parts.

  This KPI can be used to measure the generic GEN_K03 indicator as it collects data related to the production lead time of past jobs. The document (in Excel format) has been extracted from the current planning sheet used in the internal processes.

- **AID_K05 Improvement against unwanted critical events that may happen on the 3D printing processes**
  Although the available historical data is limited, since June 2024 AIDIMME manages a document to save all the detected disruptions, both internal and external. This log provides valuable feedback on past incidents, including when they occurred, its nature, and the timeline for returning to normal operations. Based on this information, AID can evaluate the current AS-IS situation and assess how effectively the organization responds to various critical scenarios. This document can also be used for GEN_K01, as describes potential future disruptions that may occur again, and can also be used for GEN_K02, as it defines the time spent to recover the full operation in the AS-IS scenario.

- **AID_K08- Improvement of waste management generated by production processes and potential cost reduction**
  Carbon footprint related information has been collected for both customers and suppliers, at least the ones which have more activity and deliver higher quantities

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(Kg). From the 3D printing machines point of view, unfortunately AIDIMME barely has information available.

The waste with higher valorisation value has been identified in order to analyse potential industrial symbiosis actions.

3.1.3. BUDATEC Pilot-Specific KPIs

In the BUDATEC (BUD) pilot, the KPIs list included two indicators which could be mapped to generic ones. They are: (1) Improvement of on-time delivery rate, that can be mapped to GEN_K03, and (2) Reduction in identification of potential disruptions, that can be mapped to GEN_K01. The resulting list of BUDATEC KPIs is presented below:

KPI ID	KPI Name	Expected Value (~)
BUD_K01	Reduction of the production time	60%
BUD_K04	Improvement in stock reduction	30%
BUD_K05	Extension of product life span	10%
BUD_K06	Reduction of the reshuffling of a Supply Chain (SC) after an unforeseen event which leads into a breakage	8 - 2 months

TABLE 3: LIST OF BUDATEC PILOT'S KPIS

- **BUD_K01- Reduction of the production time**
  At BUDATEC the production time currently is calculated within a self-developed project management tool. For each project, every worker from construction, engineering to shopfloor workers and quality management enters their working hours. The sum of it shows the production time. Problematic with this calculation is, that delivery times communicated to the customer are estimated with historic production times of similar projects and products. But downtimes of the production are not integrated in the project tool, which reduces the reliability of the estimated delivery times. So, adding these would help with the calculation. Because of the layout of the production, missing parts are not only increasing the delivery times, because of setting the production on hold, but also the production time. Semi-finished parts must be removed from their production place to hold areas until the missing parts are delivered, only to be integrated into production again. In some special cases, machines are partly disassembled to gather needed parts for projects with higher priority.
- **BUD_K04- Improvement in stock reduction**
  Through their warehouse management tool (WMS) BUD gets a stock evaluation in Euro. For critical parts, they hold up a safety stock. Critical parts are declared because of historic project data, where the parts are the reason for delayed deliveries. Because of the high cost of some parts, even if they are rarely used or standardly replaced by other parts, they remain in the warehouse. To reduce the stock, for BUD mainly the reliability of the supply chain is the pain point. The just in time production is dependent on short and reliable delivery times of their suppliers. One current solution to address this issue is to set up B-suppliers for critical parts.

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- **BUD_K05- Extension of product life span**
  For their sold machines, BUDATEC has a database to follow their products. Broken machines are replaced at the customer premises and sold refurbished to e.g. universities. To follow the machine status, BUDATEC tries to hold close contact with their customers. In newer machines the company added a counter which measures the running time. It can be read when a service employee gets access onsite. To increase the product lifespan, BUDATEC currently plans on implementing regular maintenance contracts and plans. Challenges are the willing of the customer and machines, that are rarely used. Also, standard repair and wear parts are documented and sold in advance to the customers to acquire the ability of self-repair. The set up of such standardised maintenance plan is a highly administrative and logistic act for a small company like BUDATEC.
- **BUD_K06 Reduction of the reshuffling of a Supply Chain (SC) after an unforeseen event which leads into a breakage**
  Calculating the time of reshuffling the supply chain is a very difficult exercise. It can only be estimated through the production times and the turnover. To stabilize the SC and reduce the time, BUDATEC tries to set up two different supply chains: one for customers with strict regulations and one for customers with less regulations. In some cases, parts with less quality will be assembled into the machines, to keep the delivery times. As soon as the high-quality parts are back in stock, they will be replaced at the customer site. Also, the setup of alternative suppliers, as mentioned in the indicator K04, becomes a solution to reduce the time.

It should be noted that the expected values for the generic indicators may depend on each pilot, so these KPIs are shared among the three pilots, and each pilot has different expectations regarding each one.

3.2. GENERIC KPIs

The list of generic KPIs has not changed, and just a codification as previously described was done, using the code GEN. This list is presented below:

KPI ID	KPI Name
GEN_K01	Improvement in the identification of potential risks and disruptions
GEN_K02	Improvement of time dedicated to recover the full functionality after a disruption
GEN_K03	Improvement of the on-time delivery rate
GEN_K04	Reduction of greenhouse gas emissions and energy consumption in production
GEN_K05	Reduction of amount of waste generate by lead supplier or tier-1 company in SC

TABLE 4: LIST OF GENERIC KPIS

A comprehensive spreadsheet with all the KPIs information was shared in the internal project repository so all partners could fill the relevant Information. This is structured in

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different tabs, to introduce information about pilot-specific and generic indicators for each pilot: MEDWOOD, AIDIMME, and BUDATEC.

The indicators spreadsheet was conceived to keep a track of the KPI measurements, and how are they conducted. Columns to indicate the KPIs values for months M18 (AS-IS), M27 and M33 are Included, as well as how are they expected to be achieved, and how are calculated at each stage.

Moreover, a comparison process in the KPIs of the three pilots was carried out to identify and avoid redundancies.

3.2.1. Generic KPIs in the MEDWOOD Pilot

- **GEN_K01- Improvement in the identification of potential risks and disruptions**

The information related to this KPI is being filled out in a dedicated Excel sheet, also identifying the critical resources.

It should be noted that the assessment of this indicator is complex, so the disruption table being managed is manually completed, and there are no historical values available. Therefore, the maintenance of this repository of this disruption becomes an important challenge.

The achievement of a significant improvement in this parameter becomes quite difficult. However, there is no tool in the company to address disruptions, so the availability of such resource would become highly valuable.

The number of disruptions manually managed by MEDWOOD will be taken as the basis. Actually, these disruptions are reported after they have occurred. This information could be used for the training of algorithms for the calculation of predictions, although each one needs a human review to determine the right approach and evaluate the proper anticipation to take preventive actions.

- **GEN_K02- Improvement of time dedicated to recover the full functionality after a disruption**

The company has not managed measurements related to this parameter so far. As in the previous indicator, the information related to this KPI is being fulfilled in a dedicated Excel sheet, indicating the disruption time.

It should be noted that the improvement here is expected to be measured as an improvement range. The actual registry of disruptions considers the estimated time needed to recover from each type of disruption, parameter that would be reduced through the adoption of the project solutions.

- **GEN_K03- Improvement of the on-time delivery rate**

This KPI is related to direct customers, but this is not referred to the transportation time from the MEDWOOD premises to the customer side, but the time till the preparation for the shipment of goods to the customer premises.

The information for this indicator is obtained from the ERP of MEDWOOD, taking the difference/average between the real and the estimated delivery date.

In particular, the on-time orders are managed through an Excel sheet that can be obtained from the ERP indicating any range of dates. However, this implies that there is no warning system available, and the awareness of any issue requires human supervision.

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The assessment of the improvement of the deliveries can be done through the historical delivery periods, or from the orders delivered on time.

- **GEN_K04- Reduction of greenhouse gas emissions and energy consumption in production**

The calculation of this KPI requires the manual collection of data from different sources (e.g., energy consumption, waste generation, transportation) which are not actually integrated. Indeed, the preliminary focus is on the internal production processes, excluding raw materials.

The current nature of the data should be evaluated for later process, so specific examples need to be generated. A data template for the Carbon Footprint (CF) calculation was generated by AIDIMME and fulfilled by MEDWOOD to prepare such calculation.

It is worth noting that no CF measurement is performed so far, and this is a pre-requisite to get the acknowledgement about the actual situation and then evaluate the progress achieved.

As an example, the energy consumption – which is actually an available parameter – can be compared with the units produced (e.g., by the invoicing).

It is worth noting that this indicator could be split in two specific measurements: the reduction of greenhouse gases on the one hand, and the energy consumption on the other hand. This last one can be obtained from an IoT platform that manages the energy generated by the solar panels and the energy consumed in the factory. This separation has been taken into consideration. The improvement of these measurements is expected to be measured as an improvement range.

- **GEN_K05- Reduction of waste generation by lead supplier or lead supplier in the SC**

This indicator refers to the reduction of the amount of waste generated by the lead supplier or tier-1 company in the supply chain.

To perform a proper measurement of this indicator, the specific parameter related to waste generation must be identified for each supplier.

Moreover, further information may be requested to potential suppliers to properly address this measurement. Therefore, the calculation of this KPI needs a detailed review, so there are no mechanisms available to perform a proper calculation.

3.2.2. Generic KPIs in the AIDIMME Pilot

- **GEN_K01- Improvement in the identification of potential risks and disruptions**

This indicator is strongly related to the specific indicator AID_K05 Improvement against unwanted critical events that may happen on the 3D printing processes, and therefore a similar calculation method is expected to be applied.

- **GEN_K02- Improvement of time dedicated to recover the full functionality after a disruption**

This generic KPI is also strongly related to the specific indicator AID_K05 Improvement against unwanted critical events that may happen on the 3D printing processes, with the time parameter as main difference.

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- **GEN_K03- Improvement of the on-time delivery rate**

This indicator is related to AID_K04- Reduction of the production time, and a similar approach will be followed in both indicators.

- **GEN_K04- Reduction of greenhouse gas emissions and energy consumption in production**

The information available covers the overall consumption of some premises of AIDIMME (no allocation can be made).

However, information about some particular machines could be obtained and theoretical energy calculations can be made in order to calculate the CF of a particular product. Moreover, additional insights could be obtained during the calculation process.

- **GEN_K05- Reduction of waste generation by lead supplier or lead supplier in the SC**

The gathering of the information required for the calculation of this indicator is a challenging process, so this should be gathered from all the potential suppliers.

3.2.3. Generic KPIs in the BUDATEC Pilot

- **GEN_K01- Improvement in the identification of potential risks and disruptions**

This indicator considers the installation of certificated processes like TISAX Certification (risk of lost data and knowhow) / ISO 27001 / ISO 9001, with comprehensive documentation of all processes. Also, the installation of a dashboard for filtered information from different sources is considered.

- **GEN_K02- Improvement of time dedicated to recover the full functionality after a disruption**

Software or AI software supported programs for an effectively management of resources (material, human, space, money) should take place to get such improvement.

- **GEN_K03- Improvement of the on-time delivery rate**

This KPI requires the availability of software supporting the tracking of suppliers in real time, no blind in the timeline, and support for forecasting and adequate order information.

- **GEN_K04- Reduction of greenhouse gas emissions and energy consumption in production**

This required the collection of data and real time data support. More focus in data like this and product pass preparation.

The Partial 2024 corporative carbon footprint (scope defined in NARRATE) is being calculated for facilities in Portugal and Germany.

- **GEN_K05- Reduction of waste generation by lead supplier or lead supplier in the SC**

For each supplier, the specific indicator related to waste generation must be identified. The ISO 9001 is also carried out according to sustainability since 2023.

Supplier evaluation according to ISO 9001 standard is also addressed according to sustainability since 2023.

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4. TECHNICAL BACKGROUND FOR THE EARLY DEMONSTRATOR

4.1. TECHNICAL PLANNING OVERVIEW

In deliverable D1.2 [2], the pilot user stories with their corresponding prioritized requirements, the KPIs for future impact monitoring, and a preliminary execution plan were presented. In particular, the workplan was elaborated taking the NARRATE Technology Roadmap defined in D8.2 [3] as basis. This roadmap provides valuable insights and some procedural exactness to travel a complex path marked by the technology implementations and its adequate alignment with the project objectives and the pilot expectations. For each phase, the main technical solutions and overall outputs were indicated. In the scope of such roadmap, the solutions are also called Building Blocks (BBs).

It is worth recalling the role of the Smart Manufacturing Network (SMN) as a *connected and self-orchestrated ecosystem linked end-to-end with programmable MaaS capabilities that can withstand disruptions*, what becomes an evolved operational supply chain because of the integration of an Intelligent Manufacturing Custodian (IMC) into a Supply Chain (SC) network [3].

Furthermore, a new partner, Policy Lab (PL), joined the project in M15 following the successful Hop-On call. As part of the newly introduced WP9 activities, two demonstrators will be developed (see sections 4.2.9 and 4.2.10), in addition to a contribution to the Risk Identification and Monitoring Tool. The starting point for WP9 activities has been the pilot user stories and their corresponding prioritised requirements. Since the formal accession, efforts have been initiated to align with the overall design of the NARRATE system architecture and to define the specific building blocks, enabling the implementation of phases 3 to 5 as originally planned.

The proposed roadmap consists of five different phases:

Phase 1 Foundation Establishment (from month M1 to M9) defined the vision and objectives of the project, including preliminary KPIs, data, and identifying suitable technology. This phase also covered the definition of user stories and an overall design of the system architecture.

Then, **Phase 2 Design of Digital Building Blocks** (from month M10 to M15) covered the design of strategies for disruption resilience, the production contextualization and interoperability, and the digital twin (DT) design. This second phase also included the design of other important technological resources, such as the knowledge model using DT technology, the resilience, sustainability and circularity scenarios for stress testing, and the end-to-end AI-driven visibility model and Decision Support System (DSS).

Phase 3 Development & Early Demonstration of Building Blocks (from month M16 to M24) is the one where the focus of this report is on, so the early pilot demonstration is part of this phase as well as the early Integration of the IMC and the AI platform.

In **Phase 4: System Integration, Testing & Verification** (from month M25 to M30) the pilot experimentation and demonstration is continued, and tools are implemented, such as the risk identification and monitoring, and the supplier and SMN risk assessment tools. Furthermore, solutions which were designed in previous phases continue its development, such as the knowledge model using DT technology, or the automated workflows and process orchestration.

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Finally, **Phase 5: Final Release & Rollout of Platform & Intelligent Manufacturing Custodian** (from month M31 to M36) cover diverse aspects such as security and privacy, and production reconfiguration, planning and routing. Additional systems continue its development while other key components are released: the intelligent Manufacturing Custodian and AI platform, and the final modules and platform, to be deployed, tested and evaluated.

It is recalled that the NARRATE Building Blocks introduced in D8.2 [3] will research and develop for a resilient connected and autonomous resilient supply chain ecosystem through the following functionalities:

- Real-time Visibility
- Data Contextualization
- Data Integration and Analytics
- Risk Management
- Predictive Modelling
- Collaboration and Communication
- Automated Decision Support
- Continuous Improvement
- Adapting Planning and Execution
- Compliance and Regulatory Management
- Customer Experience

After the consideration of the input collected in Phase 2 what led to the design of the different BBs, Phase 3 is focused on the development of these components and the early demonstrator. WP5 will validate the developed BBs through the releases #1 and #2 of the NARRATE platform. The first release of the early pilot demonstrator (M24) will partially integrate BBs, tools, the IMC, and the AI platform taking one single pilot demonstrator as reference, with the aim of presenting the expected functionalities. Moreover, the final release of the platform will consider the feedback retrieved from the three pilots.

4.2. SOLUTIONS INVOLVED IN THE EARLY DEMONSTRATOR

This section provides a brief description of the technical solutions involved in the NARRATE early demonstrator considering the planned roadmap introduced in the previous section and the availability of these solutions.

Each technical solution is essentially a modular component that represent a particular functionality required for the proper execution of the SMN in terms of intelligence and resilience. These components support the generation, the evolution and the reconfiguration according to targeted objectives and unplanned disruptions.

The provided descriptions are not much technical-oriented, so technical details about each component can be found in deliverable D1.4 [5]. In this section, the focus is on describing the scope and main functionalities, as a quick preview to provide an enhanced awareness from the pilots' perspective.

It is worth recalling that the building blocks defined in D1.4 [5] represent overall functionalities which can be implemented by one or more technical solutions (aka modules, or tools).

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4.2.1. Disruption Resilience

BUL in the NARRATE project develops two tools: The Resilience Strategy & Tool (release date: M24) and the Supplier & SMN Risk Assessment Tool (release date: M30), designed to enhance the resilience of Smart Manufacturing Networks (SMNs). The Resilience Strategy & Tool, developed under Task 2.1, focuses on creating comprehensive resilience strategies to ensure SMN continuity when unforeseen events occur. This tool incorporates a systematic approach to understand and classify various Internal and External Risks & Disruptions that may impact SMN. Through advanced analytics methods, it helps organizations develop proactive strategies by assessing resilience KPIs, including Time to Recovery and Loss of Operating Level. The tool quantifies deviations in critical assets at the network level (production, transportation, and warehousing) in terms of cost, quality, quantity, and time (delay), enabling companies to understand how risks and disruptions impact their operational efficiency.

The Supplier & SMN Risk Assessment Tool complements the first tool by providing detailed analysis of disruptive events' impact on the manufacturing network. It employs sophisticated algorithms to identify risk patterns and assess suppliers' potential risks to the overall network. The tool conducts stress testing across the supply chain network, analysing scenarios at three levels: supplier (two tiers), manufacturing (lead manufacturer and subcontractors), and customer. This comprehensive approach helps organizations identify critical vulnerabilities and develop more targeted and effective resilience response plans.

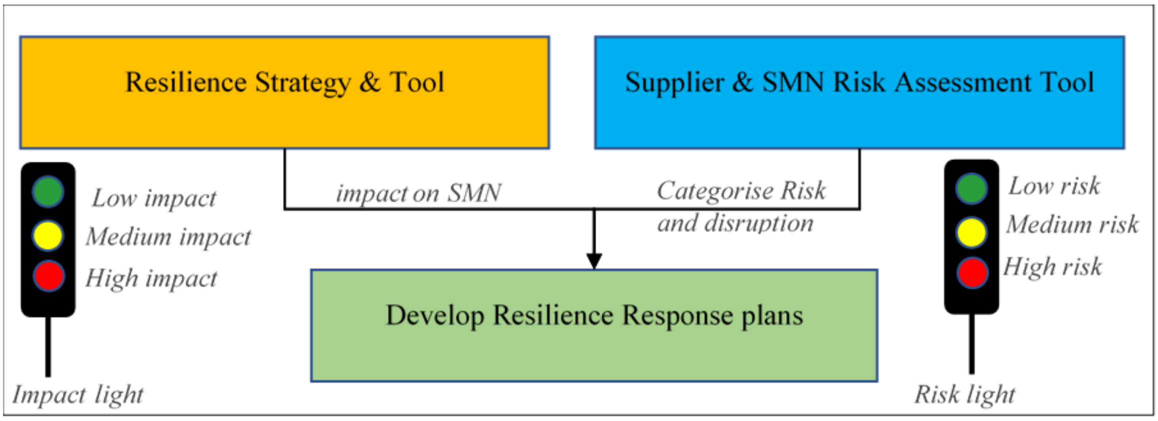

Figure 4: Overall diagram of the disruption resilience tools

Both tools will be integrated into the NARRATE Platform and implemented within the AI Platform developed in WP6, ensuring seamless access and utilization across the network. These tools directly address the core objectives of WP2 (O2.1-O2.3) by providing a comprehensive framework for disruption management and resilience strategy development in SMN.

It should be noted that although the resilience strategy described in this section requires both components, given that this report is focused on the early demonstrator, the Resilience Strategy & Tool (M24) has been prioritized, to be later linked with the SMN & Supplier Risk Assessment Tool (M30).

4.2.2. Neuro-Symbolic Decision Support System

The Neuro-Symbolic Decision Support System (NSDSS) developed in NARRATE combines the capabilities of Large Language Models (LLMs) to understand natural language and

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analyse unstructured data with the power of symbolic reasoning, based on rules, ontologies, and knowledge graphs. This hybrid architecture allows the system to act as an expert assistant that not only interprets complex questions formulated by operators, but also provides recommendations grounded in verifiable and traceable criteria. The neural layer simulates reasoning, identifies patterns or anomalies in large volumes of data (e.g., production histories or logistics incidents), while the symbolic layer ensures compliance with formal conditions such as sustainability regulations, procurement policies, or business rules. All this is achieved through an interface that delivers clear explanations in natural language and continuous learning through human feedback.

During the early phases of the project, the NSDSS is being conceived as a central component of the Intelligent Manufacturing Custodian (IMC), with planned integration alongside digital twins, industrial data models, and defined workflows. Its objective is to enable operators to pose natural language queries—such as "Which alternative supplier is best suited if the current one fails?"—and have the system translate them into interpretable symbolic structures. In subsequent phases, this reasoning will be further enriched with the adaptive capabilities of LLMs, leveraging historical data, operational context, and formal knowledge to simulate scenarios and recommend optimal strategies. This combination will offer an explainable and robust tool to support decision-making in industrial environments in the face of unexpected events.

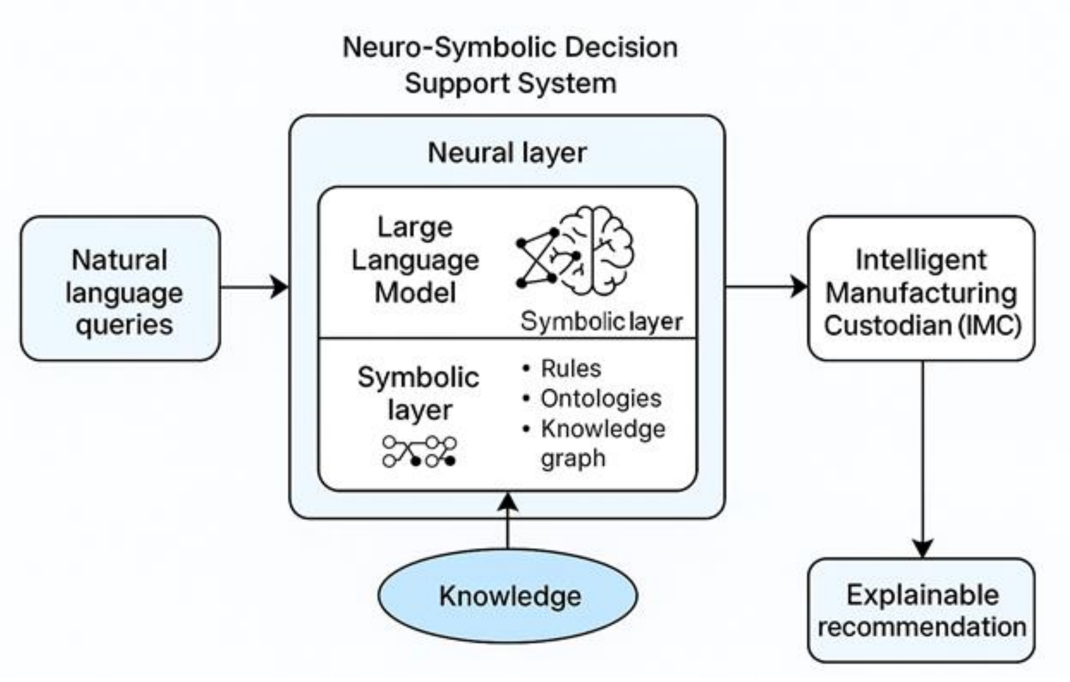

Figure 5: Diagram of the neuro-symbolic DSS

4.2.3. Automated Workflows & Production Process Orchestration

As part of the NARRATE project, FhG is developing a module for orchestrating automated workflows and production processes. The aim is to combine individual digital twins (DTs) into a networked, digital overall process from order confirmation to delivery. Automated workflows identify risks and errors at an early stage, initiate countermeasures such as the selection of alternative suppliers and optimise processes in terms of environmental and energy efficiency. Asset Administration Shells (AAS) form the basis for this. As standardised, digital representations of objects (e.g. machines or products), they bundle all relevant information and enable data exchange across the entire life cycle. Various

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sub-models of the AAS, provided by the Industrial Digital Twin Association, serve as the basis for further development.

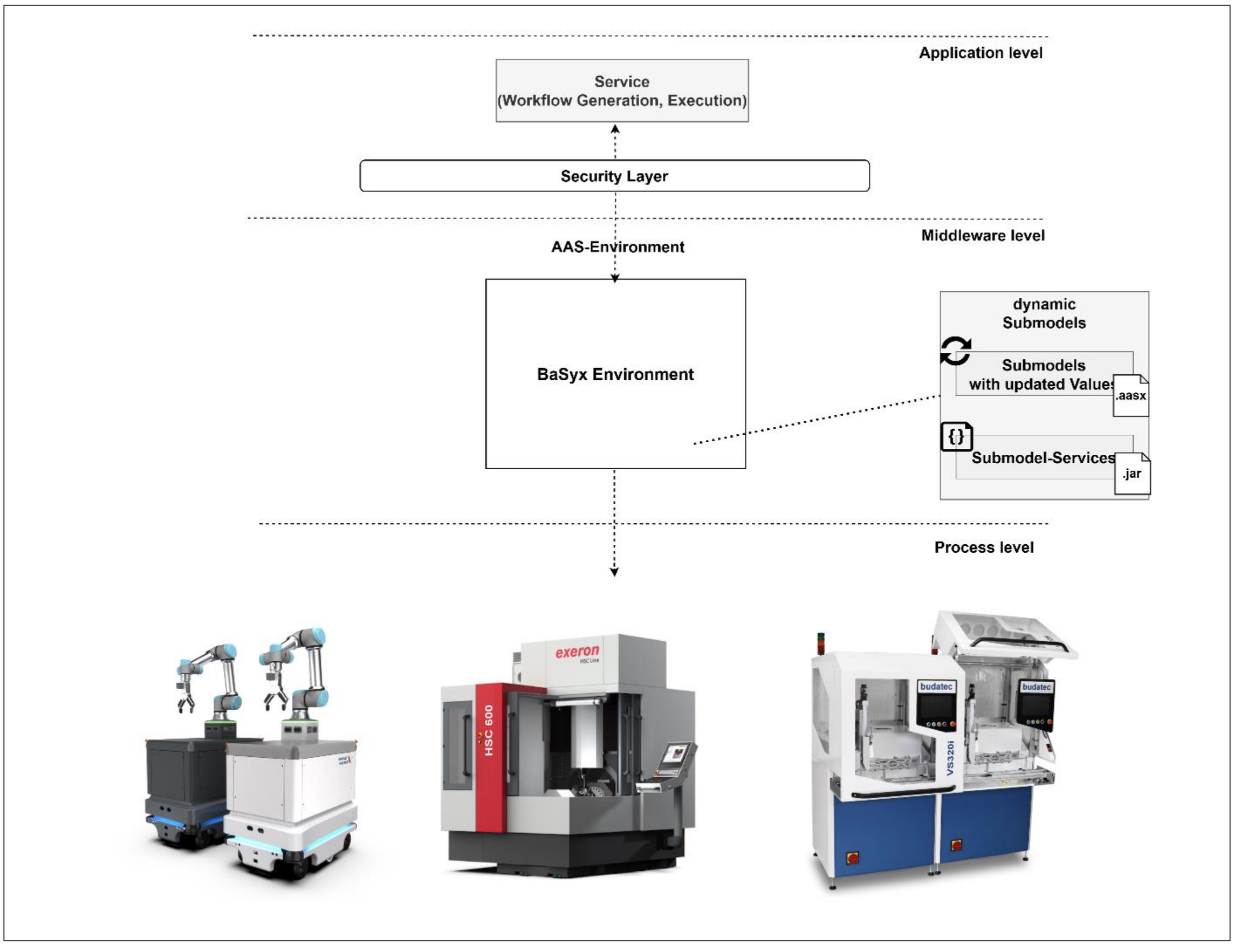

Figure 6: BaSyx-architecture

The overall architecture of the demonstrator will consist of three areas:

1. Application level: provides the actual Workflow Generation and Execution applications. These applications will work on the process level data provided by the middleware
2. Middleware level: Eclipse BaSyx is used for the middleware, which is an intermediary between assets and IT systems. It provides standardized interfaces based on the asset administration shell (AAS), integrates various devices and systems regardless of manufacturer and thus enables the simple networking, management and orchestration of digital twins.
3. Process level: All assets are located at the process level. These assets must be enabled to ensure standardized communication with the middleware.

4.2.4. Production Contextualization Services

The Production Contextualization Services in NARRATE serve as a foundational layer for transforming raw production data into high-context, semantically enriched, interoperable intelligence. These services are enabled by the Federated Data Integration Framework (FDIF), which orchestrates the secure, standardized, and context-aware aggregation of data across the Smart Manufacturing Network (SMN).

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At their core, the Production Contextualization Services bridge the gap between heterogeneous, decentralized data sources the Blueprint Management System and the Intelligent Manufacturing Custodian (IMC), empowering real-time decision-making, Digital Twin synchronization, traceability, and AI-driven analysis. The Key Capabilities and Enabling Technologies are:

1. **Standardised Ontologies and Metadata Models**

   This capability enables semantic harmonization across distributed systems by applying common vocabularies and metadata standards creating Semantic Data Catalogues and Process and Asset Context Models. It ensures that:

   - All data assets—from machine logs to sensor feeds—are annotated using a shared ontology (e.g., CDIF).
   - Data interoperability is guaranteed across organizational and system boundaries.
   - FAIR principles (Findable, Accessible, Interoperable, Reusable) are embedded at the foundation.

   These ontologies define how different production, process, and asset data are described and discovered. The result is a backbone of intelligent querying, traceability, and reasoning across the SMN.

2. **Metadata-Aware APIs for Interoperability**

   Production Contextualization Services are delivered through lightweight, secure APIs that not only transport data but also preserve its semantic meaning, access rules, and provenance. These APIs enable:

   - Seamless exchange of production, logistics, and quality data between partner systems.
   - Embedding of metadata such as data lineage, ownership, timestamps, and source trust level in every payload.
   - Support for decentralized architectures via federated access models that respect local data sovereignty.

   These APIs act as the connective tissue of the contextualization layer, ensuring data flows meaningfully, securely, and intelligibly across digital twins, analytics engines, and user-facing dashboards.

3. **Contextualised Aggregation and Semantic Enrichment**

   The FDIF supports real-time semantic enrichment of raw data at the point of ingestion—whether from IoT sensors, machine logs, human inputs, or external systems. Enrichment includes:

   - Timestamping, geolocation, and source system metadata
   - Operational context, such as batch number, machine status, and material ID
   - Quality indicators, enabling traceability and analytics

   This contextualized data becomes the input for Digital Twin simulations, production forecasting, sustainability evaluations, and machine learning training. By enabling context-rich, interoperable data, these services provide the IMC with a high-resolution, semantically aligned mirror of the physical world, driving intelligent orchestration, real-time resilience, and strategic foresight.

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4.2.5. Production Planning & Process Routing System & Algorithms

As a key contributor to the NARRATE project, INSA is designing an advanced tool comprising two interconnected modules, including Production Planning and Reconfiguration, to strengthen production resilience in Smart Manufacturing Networks (SMNs). The first module, AI-driven Production Planning (to be delivered by M24 and M33), is being developed under Task T4.3. This module extends the Decision Support System (DSS) to optimize production planning and process routing across the SMN ecosystem. This module receives and process data and information on disruption scenarios (from WP2) to prescript proactive scheduling solutions and generate actionable insights through a predictive analytics engine. These insights feed into a mathematical model that recommends proactive measures, such as resource allocation or timeline adjustments, to mitigate risks before disruptions happen. The primary objective of the module is to minimize two well-known resiliency KPIs: lost production capacity and recovery time (come back to initial situation as soon as possible).

The Production Reconfiguration module, developed under Task T4.5, addresses reactive decision-making to ensure operational continuity in SMNs. Building on the vulnerability analysis and contingency plans generated in Task T4.3, this module dynamically readjusts production workflows and network configurations after disruptions occur. These disruptions, whether stemming from supplier delays, manufacturing system failures, or transportation bottlenecks, trigger the module to generate targeted recommendations aimed at minimizing lost capacity and accelerating recovery time. Key reconfiguration strategies include rescheduling production orders, resequencing tasks, or temporarily subcontracting through Manufacturing-as-a-Service (MaaS) platforms. Its general goal is to sustain productivity and reduce downtime, thereby complementing the proactive risk-mitigation capabilities of the earlier AI-driven module (T4.3).

The tool will be implemented within the AI platform created in WP6 and integrated with the NARRATE platform, guaranteeing efficient network access and use. This tool directly addresses WP4's main goals (O4.4, O4.5, O4.6).

4.2.6. Intelligent Logistics & Warehousing System

The production planning and process routing, described in 4.2.5, is directly connected with logistics, transport and warehousing operations. In addition to this, there is a connection with the information flow between the manufacturers and their suppliers. The interconnection of these sources allows to have visibility of the events in the entire chain for all the involved in production and allow the IMC to make any appropriate decision to mitigate negative impacts in case of disruption.

Figure 7: Intelligent logistics & warehousing system

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To achieve this, the following Digital Twin frames have been established:

- Manufacturer input: inventory of critical elements to be stored in the warehouse. Quantity, number, size, volume, specificities of storage (e.g. temperature, date of expire, etc.) or periodicity of arrival, among others. Analysis of disruption scenarios that are considered critical for them.
- Manufacturer-supplier input: number of elements in each of the orders, estimated date of arrival at the warehouse.
- Logistics operator input: inventory levels of each element periodically updated, orders for shipment to manufacturer, location of elements in the warehouse.
- Transport operator input: routes used from supplier to warehouse, routes from warehouse to the manufacturer. Special requirements of the routes, if any, for specific elements.

The flow of information here described is the baseline of Task 4.4-*Intelligent Logistics and Warehousing*, coordinated by DHL. Technical partners of this task will develop the required algorithms for the system implementation, based on the requirements, functionalities and data sets established by DHL, as a logistics operator, and MIC as manufacturer. AI and IoT will be used for achieving an automated technology to optimise warehousing and transport operations, in coordination with the production planning and process routing.

In particular, this system allows an intelligent decision-making methods and algorithms to ensure the continuity of production, transportation, warehousing operations (O4.3), advanced production planning approach to enhance the ability of the SMN to respond unanticipated external disruptions (O4.4), better understanding of the impact of external events (O4.5), and support of reconfiguration of SMN considering resilience, sustainability and circularity aspects (O4.6).

4.2.7. Risk Identification & Monitoring Tool

The Risk Identification & Monitoring tool allows an analysis (e.g., of the SMN) using real-time risk identification and a real-time dashboard. The solution will consist of three core components that in sum establish a flexible and easily configurable solution, namely a Complex Event Processing (CEP), a messaging broker and a lightweight IoT dashboard. At its core, a complex event processing engine allows for real-time detection of meaningful pattern or relationships among multiple incoming events, as well as correlation and aggregation of disparate event streams.

Unlike systems that simply log or monitor individual occurrences, CEP can correlate different events, sometimes from different sources, to form a higher-level understanding of what's happening. For instance, in a financial system, CEP might detect a possible case of fraud by recognizing a series of rapid transactions across different accounts and geolocations that would be considered harmless individually but suspicious in combination. This technology allows to analyse and respond to events as they occur in real time. It's designed to process streams of information—such as sensor readings, disruptions, user interactions, financial transactions, environmental hazards, or network logs—as they flow through a system, allowing the IMC to make fast, informed decisions without waiting for traditional batch processing or storage-based analysis.

The engine is built around the MQTT protocol—a publish/subscribe messaging model that's designed to be simple, efficient, and ideal for scenarios where network bandwidth is limited or devices are constrained in terms of power and processing capability. Rather than having devices communicate directly with each other, MQTT introduces an

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intermediary known as a broker. Devices or applications that generate data (called publishers) send their messages to this broker, tagging them with a topic (such as factory/machine1/status). Other devices or services (known as subscribers) register their interest in specific topics. The broker then ensures that any new messages published to those topics are immediately forwarded to the appropriate subscribers.

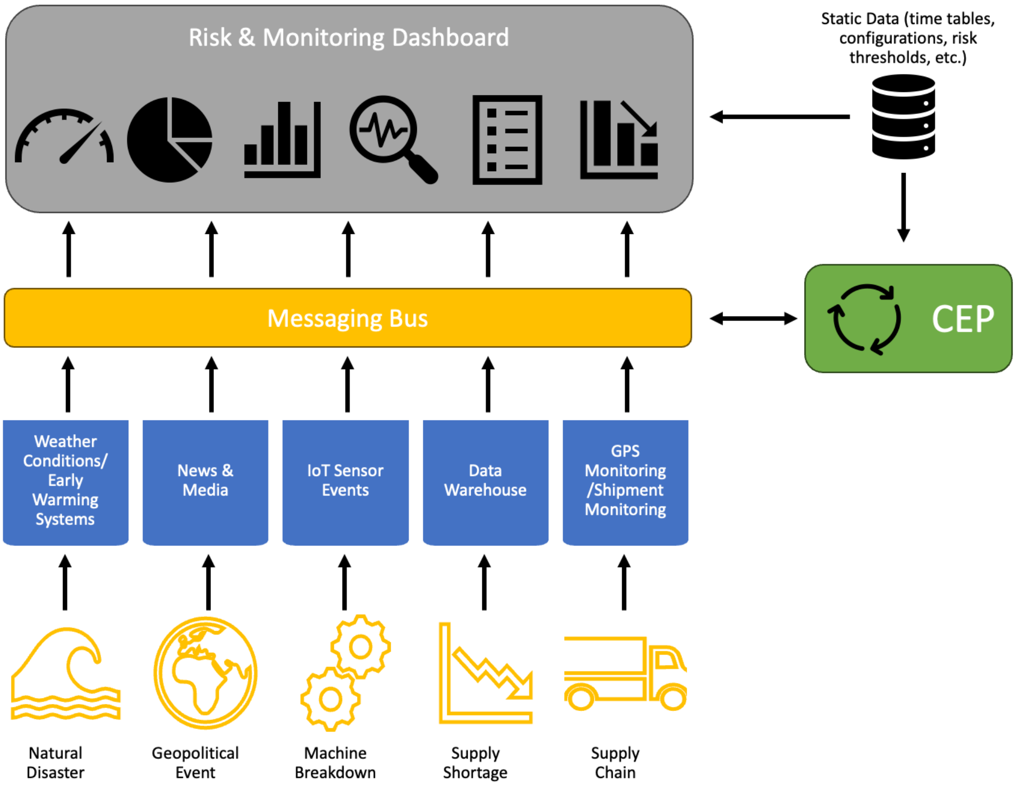

Figure 8: Overview of the risk and monitoring dashboard

In this setup (c.f. Figure 8 above), the event messaging engine comprises not just the broker but potentially additional logic that processes messages, filters them, applies business rules, or routes them to other systems (e.g., databases, dashboards, or control systems). For example, in a factory, sensors might publish temperature readings to a specific topic. The messaging engine could monitor this stream, and if a certain threshold is exceeded, trigger an alert or activate a cooling system. This model offers strong decoupling between message producers and consumers, scalability, and flexibility. Systems can evolve or scale independently without needing tight integration between components. As such, event messaging engines using MQTT are a fundamental building block in modern, event-driven architectures.

The IoT dashboard provides a digital interface that allows users to interact with and monitor data from Internet of Things (IoT) devices, the messaging bus or aggregated events from the CEP. It transforms raw data collected by sensors into understandable visuals such as graphs, charts, and maps, helping users see trends, detect issues, and make informed decisions. In industrial environments, an IoT dashboard becomes even more powerful. It might display real-time data from machines on a factory floor, flagging anomalies before they become critical failures. This allows managers to schedule maintenance proactively, reducing downtime and saving costs.

The afore mentioned risk analysis & monitoring solution will allow quick response to potential disruptions by including several sources and event streams (e.g., from news

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feeds, social media, news, twitter, LinkedIn, etc.). In addition, the use of IoT sensors allows early detection of potential supply chain disruptions via asset tracking. The above data will be collected and analysed, also employing techniques such as CEP, that permit correlation and swift reaction to events.

4.2.8. Digital Twin Management Tool

The Digital Twin Management Tool is a key enabler of NARRATE's vision for resilient and adaptive Smart Manufacturing Networks (SMNs). At its core is the Blueprint Management System (BMS), which is the digital intelligence layer of the NARRATE architecture that models and structures manufacturing and supply chain information via two tightly integrated components: **Blueprint Frames** and the **Digital Twin Processing Language (DTPL)**.

1. Blueprint Frames – Structured Digital Representations

The BMS uses **Blueprint Frames** to semantically model the operational dimensions of a Smart Manufacturing Network (SMN). Each frame abstracts critical information related to suppliers, products, production processes, logistics, sustainability, and more. The twelve key Blueprint Frames include:

- **Supplier & SMN Frames**: Model supplier capabilities and SMN structures for sourcing and network reconfiguration.
- **Product & Production Frames**: Capture design, BoM, manufacturing processes, and real-time operational performance.
- **Sensor, Logistics & Warehousing Frames**: Provide live data on machine status, inventory, and transportation for agile coordination.
- **Quality, Sustainability & Compliance Frames**: Ensure standards adherence, monitor environmental impact, and drive quality.
- **Disruption & Resources Frames**: Identify operational risks and optimize resource allocation obtaining input from the Resilience Strategy & Tool in WP-2.

These blueprints are:

- **Modular and domain-specific**, capturing knowledge such as supplier capabilities, production workflows, quality metrics, sensor data, and regulatory constraints.
- **Continuously updated**, serving as the real-time data substrate for operational control and planning.

Together, these frames enable programmable, scalable, and semantically rich Digital Twins that power the IMC's resilience and optimization capabilities. The tool ensures interoperability, real-time synchronization, and secure access across the SMN, transforming static supply chains into intelligent, self-orchestrating ecosystems.

2. DTPL – Semantic Processing and Orchestration Layer

The **Digital Twin Processing Language (DTPL)** complements Blueprint Frames by acting as the orchestration and interaction mechanism that enables the IMC and human experts to interpret, control, and coordinate digital twins and their underlying blueprints.

DTPL processes the structured information contained within Blueprint Frames, allowing for:

- **Semantic Navigation**: DTPL queries and reasons over multiple interconnected frames (e.g., extracting all suppliers that meet specific sustainability and lead-time constraints).

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- **Cross-Frame Integration**: It allows operations that span several frames—for example, combining data from the **Product**, **Supplier**, and **Production** Frames to optimize make-to-order decisions dynamically.

3. Functional Coupling of Blueprint Frames and DTPL

Each type of Blueprint Frame contributes specific data structures and semantics that DTPL can interact with, as indicated in Table 5 below:

Blueprint Frame	DTPL Interaction
Supplier & SMN Frames	DTPL identifies viable SMN configurations, filters suppliers by capabilities, and evaluates resilience under disruption scenarios.
Product Frame	DTPL extracts BoMs, identifies required manufacturing methods, and configures workflows based on material constraints or design variations.
Production Frame	DTPL models and optimizes workflows, allocates resources, and reschedules operations in response to IoT-triggered events.
Real-Time Sensor Frame	DTPL listens for event triggers (e.g., machine overheating) and initiates adaptive responses, such as rerouting tasks or reducing loads.
Logistics & Warehousing Frames	DTPL processes logistics updates to adjust production scheduling or inventory provisioning.
Quality Assurance Frame	DTPL queries QA records for compliance and defect trends and integrates these into predictive maintenance logic.
Sustainability Frame	DTPL evaluates operations against carbon and waste thresholds, triggering reconfiguration if environmental KPIs are at risk.
Disruption Frame	DTPL supports scenario simulations and fallback strategies by analysing historical and real-time disruption data.
Resources Frame	DTPL maps available machine capabilities to product requirements and evaluates alternative production paths.
Regulatory Compliance Frame	DTPL ensures all operations are compliant with current standards before execution begins.

TABLE 5: DESCRIPTION OF DTPL INTERACTIONS FOR EACH BP FRAME

4. Salient DTPL Features in Practice

- **Semantic Awareness & Interoperability**: DTPL leverages the ontological consistency across all Blueprint Frames to standardize and streamline data interpretation across the SMN.
- **Event-Driven Processing**: The DTPL uses information from the Risk Identification & Monitoring tool in WP-2 to enable the IMC to dynamically respond to conditions such as machine failures or shipment delays by triggering rule-based reconfigurations or simulations.
- **Modular, Graph-Based Syntax**: Workflows can be composed graphically from modular DTPL blocks referencing specific blueprint content, such as [Sustainability: CheckCO2Compliance].

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- **Declarative Intent, Context Awareness**: Users (human or IMC) can specify high-level goals like optimize delivery time under current production and logistics constraints, and DTPL uses Blueprint Frame data to resolve and enact the intent.

5. Integration with MaaS and the IMC

DTPL acts as the **programmable control language** that enables **Manufacturing-as-a-Service (MaaS)** by exposing configurable manufacturing capabilities via Blueprint Frames. For instance, using DTPL, the IMC can:

- Automatically compose distributed manufacturing workflows across multiple SMN participants.
- Simulate alternative configurations using real-time updates from Sensor and Logistics Frames.
- Prioritize sustainability or delivery speed based on contextual triggers or service-level agreements.

4.2.9. Smart Advisor for the Identification of Export Opportunities

Based on D1.1 [1], there is a clear demand for tools that apply predictive modelling and support strategic responses to disruptions. With the major changes in the international trade in 2025, the urgency to address the potentially changing demand, has increased.

This was well anticipated in D2.1, on 'External Risks and Disruptions' that "arise from disruptions occurring outside the company's facilities, including issues at supplier plants, transportation delays, or interruptions in retail operations" (p. 14), including geopolitical events (p. 15). Numerous relevant detailed risks were identified (pp 19-20), including 'market uncertainties', 'cancelled or changed orders', etc. D2.1 also emphasizes the importance of developing resilience strategies at both the system and operational levels for manufacturing companies and the need for diversification strategy at the system level, that 'may involve diversifying the supplier base, expanding into new markets, or developing a diverse product portfolio' (p. 24).

As a response to pilot user demands and in alignment with D1.1 [1], D1.2 [2], D2.1 [6], D8.2 [3] an export opportunities advisor will be developed. This module is a decision support system for the identification of opportunities for the diversification of exports to new destination markets, developed by PL by M30. This tool identifies export promotion opportunities for individual products and markets by evaluating the overall attractiveness of markets (including country risk, economic size, and growth projection), the market potential of products (assessed through revealed comparative advantage and product complexity), as well as market growth and entry conditions. The model is comprehensive, encompassing over 5,000 6-digit HS World Customs Organisation product groups. For analysing such data, the UN Comtrade database [7], is utilised. The results will be presented as D9.2 demonstrator.

4.2.10. Smart Advisor for Alleviation of Critical Import Dependencies

Based on D1.1 [1], users require tools that support real-time monitoring of supplier performance and disruption forecasting. This includes predictive analytics that can identify risks such as delays, shortages, or quality issues, as well as automatic notification systems that alert decision-makers when predefined thresholds are exceeded. Beyond monitoring, users have expressed the need to provide analytical suggestions for diversification. This includes simulations of alternative sourcing scenarios and risk

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assessments to help identify suitable backup suppliers. The aim is not only to react to disruptions but also to strategically enhance the resilience of the supply network through diversification and forward-looking planning. D1.2 [2] and D8.2 [3] further refine and contextualise user demand for analysing supplier diversification and supply risks. Across all pilots, users such as purchase managers and production planners emphasise the urgency of identifying substitute suppliers and responding to disruptions with agility.

The current Smart Advisor will focus on 'External Risks and Disruptions' from a strategic perspective. This includes scenarios such as the potential loss of a critical supplier without an easy replacement, fluctuations in raw material costs, and similar issues, as outlined in D2.1 [6].

A respective module is designed to analyse the complex web of trade relationships and dependencies that the project partner countries have with various global suppliers. This module serves as a tool for industry leaders to analyse and strategize about mitigating risks associated with reliance on a limited number of foreign suppliers for essential production inputs. The module identifies potential for diversification of suppliers and includes an analysis of supply risks on the level of individual products. The results will be presented as D9.1 demonstrator.

4.3. OVERALL ARCHITECTURE

The reference architecture determines the design, integration, and evolution of the SMN supporting key aspects such as standardization and interoperability (homogeneous data models and interfaces), scalability and modularity (definition of BBs as scalable and replaceable modules, technological alignment (provide compatibility among rising and established industrial technologies), guides for design and implementation (enable the building of future-proof and adapted production networks), governance and compliance (supporting important features such as traceability and security by user management).

In the scope of NARRATE, the construction of intelligent, adaptable and resilient ecosystems for both supply and manufacturing become essential, and this is supported by the definition of an appropriate reference architecture. This structures the innovation (innovative systems can be integrated into extended systems), the orchestration (communication between systems and handling of disruptions), the resilience-by-design (predictive monitoring and reconfiguration as base capabilities), and the collaboration (a common language for partners to discuss operational and technical aspects).

The reference architecture for the NARRATE project described in D1.4 [5] provides risk visibility, reconfiguration, and resilience-by-design strategies to the manufacturing networks, through the orchestration performed by the IMC and enabled by a smart Industrial IoT platform. The IMC orchestrates, aggregates, analyse, and spreads information across the SMN.

The modular Building Blocks (BBs) approach facilitates the creation, operation and reconfiguration of the SMN, providing essential functionalities: supply chain resilience by monitoring through DT, SMN reconfiguration in response to events, programmable MaaS considering the production capabilities as services, and end-to-end visibility and decision support through insights generated by the IMC and obtained by federating data across the SMN.

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Both users and the IMC interact with the SMN through the Digital Twin Processing Language (DTPL) to access and process data from the digital ecosystems (e.g., ERP, MES) of the parties involved.

From the user's perspective, a pilot user should have two entry points to interact with the platform checking problems and solutions. The FIGURE 9 below shows the overall solutions' architecture from the IMC's physical and functional perspective.

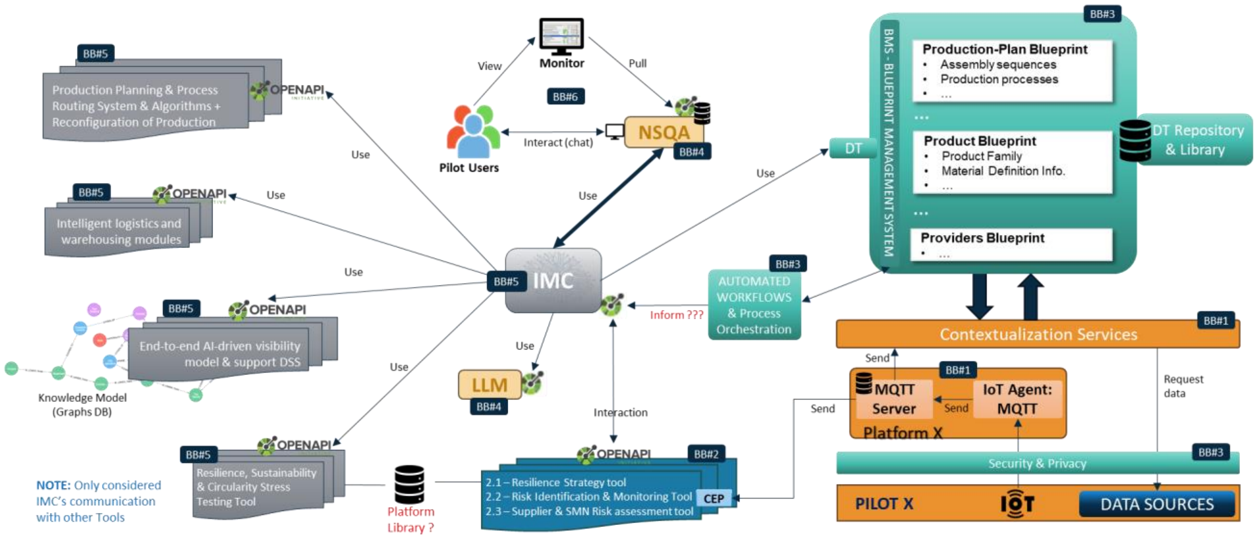

Figure 9: Core components of the architecture (WP6) including IMC's physical & functional perspective

The considered entry points are:

1. Real time Interaction with the Neuro-Symbolic Question Answering (NSQA)

   On this first case the user interacts with the NSQA through a chat box integrated in a web interface stating a problem to solve.

   This problem written in natural language is converted into machine language between the NSQA, the IMC and the Large Language Model (LLM). The IMC will then analyse this machine problem and extract and order all the actions needed to find a solution. Then the IMC executes those actions calling the different building blocks (BB#2, BB#3, BB#4, and BB#5, naming from D1.4 [5]) to gather the required answers. Some of the answers will be the input of some other Building Blocks.

   As an example, the IMC may call the Digital Twin (DT) to refresh all the required data from the pilot data sources based on the presented problem to work with the latest data available in these pilot's data sources.

   The IMC will finally compose all the different answers from the different questions into one single answer and transform that into natural language with the LLM to be sent to the pilot user via the chat box integrated in a web interface (NSQA).

2. Monitor in Realtime what problems are being detected by the system and what solutions the platform is finding to face those drawbacks.

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This second case is the same as the first one but with the difference that there is no direct interaction of the pilot user with the system. Instead of this, the pilot user can monitor all the problems the platform is detecting (e.g., via the Risk identification & Monitoring tool (BB#2), and the answers the IMC is compiling for every specific problem, watching them from the "monitor" web interface.

5. OVERALL FULFILMENT OF REQUIREMENTS

This section covers the fulfilment of the requirements by the proposed technical solutions. In this regard, a clear distinction should be made between pilot-specific and generic requirements. Considering this last set of requirements to be virtually common to all the three pilots, they have been considered particularly relevant for the early demonstrator and its corresponding fulfilment assessment.

Given the main focus on the early demonstrator, the list of requirements defined in D1.1 [1] and D1.2 [2] was conceived as a wishful list, which is indeed quite extensive and ambitious. In fact, many requirements reported in that preliminary elicitation were not aligned with the scope of the project.

A mapping between the pilot requirements and the proposed technical solutions was conducted to provide an overall vision of the technical coverage provided by NARRATE in relation to the pilot expectations.

This mapping represents the specific contributions of the solution to the specific demands from the pilots. In this regard, it is of interest to note that none of the proposed BBs aim at offering a standalone solution, so their effectiveness relies on the collaborative integration within the platform and the IMC framework.

5.1. GENERIC REQUIREMENTS

The complete list of generic requirements with a brief description can be found in the annex.

The FIGURE 10 below shows an overall mapping of the coverage of the generic requirements defined in WP1 by the proposed solutions for the early demonstrator.

	Disruption Resilience	Neuro-Symbolic Decision Support System	Automated Workflows & Production Process Orchestration	Production Contextualization Services	Production Planning & Process Routing System & Algorithms	Intelligent Logistics & Warehousing System	Risk Identification & Monitoring Tool	Digital Twin Management Tool	Smart Advisor for the Identification of Export Opportunities	Smart Advisor for Alleviation of Critical Import Dependencies
SC	75%	75%	0%	0%	100%	50%	50%	50%	25%	25%
WN	0%	14%	43%	0%	0%	71%	57%	43%	29%	29%
LM	0%	50%	0%	0%	0%	100%	25%	50%	0%	0%
DM	33%	33%	67%	0%	0%	0%	100%	0%	67%	67%
MM	0%	67%	100%	33%	0%	0%	33%	67%	0%	0%
AC	43%	100%	0%	0%	29%	0%	0%	0%	0%	0%
PM	20%	20%	0%	20%	0%	20%	20%	80%	0%	0%
EM	0%	80%	0%	0%	0%	0%	20%	60%	0%	0%
ST	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
PJ	0%	67%	0%	0%	0%	0%	67%	0%	0%	0%

Figure 10: overview of the fulfilment of generic requirements by the proposed solutions

In the FIGURE 10 above, each percentage indicates the proportion of generic requirements of each category (e.g., SC, WN, etc.) which are covered by each technical

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solution. Considering that these results are focused on generic requirements, they apply to all the three pilots. For the obtention of these results, those generic requirements which are not expected to be covered by any tool were removed. They are:

- DM_4: Automated information gathering and processing with manual upload feature.
- MM_4: interface for quality management with alert system for distortions/deformations and feedback collection from customers and internal departments.
- PM_6: interface with adjustment features into production planning and individual projects regarding different KPIs
- PM_7: Historical data analysis and automated assignment into relevant projects, departments.
- PM_8: Platform to manage quality reports, feedback information and suggestions made by the analytical capabilities.
- ST_1: Platform to manage service orders and appointments, maintenance notification, track of changes and service dates, worker and service equipment available)
- ST_3: interface for information to customer (delivery status, service appointments, changes made, notifications, design guidelines)

5.2. PILOT-SPECIFIC REQUIREMENTS

For the coverage of pilot-specific demands by the solutions proposed in NARRATE, a preliminary wide range of requirements has been taken.

However, the early demonstrator needs to be focused on those user stories/requirements which are expected to be covered by the tools through the use cases once the early integration has been completed.

Therefore, the list of pilots' User Stories mostly covered by the proposed tools are indicated in the TABLE 6 below.

Solution name	MEDWOOD	AIDIMME	BUDATEC
Disruption Resilience	MIC_01 MIC_03 MIC_04 MIC_05 MIC_07	AID_11 AID_12	BUD_13
Neuro-Symbolic Decision Support System	MIC_01 MIC_03 MIC_05 MIC_06 MIC_14	AID_01 AID_02 AID_30	BUD_07 BUD_09 BUD_10 BUD_16 BUD_17
Automated Workflows & Production Process Orchestration	MIC_01 MIC_07		BUD_24

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Production Contextualization Services	MIC_01 MIC_07 MIC_12 MIC_14		BUD_02
Production Planning & Process Routing System & Algorithms	MIC_01 MIC_09 MIC_11	AID_12	
Intelligent Logistics & Warehousing System	MIC_07 MIC_13 MIC_14 MIC_15 MIC_17 MIC_19	AID_01 AID_02 AID_03 AID_05 AID_06 AID_11 AID_26	BUD_03 BUD_06 BUD_07 BUD_10 BUD_13 BUD_15 BUD_18 BUD_20 BUD_23
Risk Identification & Monitoring Tool	MIC_07 MIC_08 MIC_13 MIC_17	AID_03 AID_06 AID_09 AID_18 AID_24	BUD_09 BUD_10 BUD_15 BUD_23
Digital Twin Management Tool	MIC_01 MIC_04 MIC_05 MIC_08 MIC_14 MIC_15 MIC_16 MIC_19 MIC_21 MIC_22 MIC_27	AID_19 AID_30	BUD_02 BUD_06 BUD_07
Smart Advisor for the Identification of Export Opportunities	MIC_13 MIC_17	AID_06	BUD_09
Smart Advisor for Alleviation of Critical Import Dependencies	MIC_05 MIC_13 MIC_17	AID_03 AID_06	BUD_07

Table 6: Overview of pilot-specific user stories covered by the proposed solutions

The complete list of user stories and its corresponding pilot-specific requirements can be found in the annexes 1 (MEDWOOD), 2 (AIDIMME) and 3 (BUDATEC) of deliverable D1.2 [2].

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The list of user stories presented in the TABLE 6 above is presented just to provide an overall view of the coverage provided by the different technical solutions. However, the scope of the early demonstrator is expected to be focused on the particular applicability through the early use cases, and a selection of specific user stories will therefore be selected to take part in the early pilot demonstrator. A first approach of this selection can be found in the early use cases section below.

6. PILOT PREPARATION OF EARLY DEMONSTRATION

The preparation activities carried out during this first stage targeting the early demonstrator cover tasks of a different nature.

The pilot-specific and the generic KPIs have been revisited and analysed for each pilot, evaluating how are they currently calculated, what are the target expectations, and how can they be improved through the adoption of the technical solutions provided by NARRATE. Furthermore, the datasets from which the main information for the measurement and monitoring of each KPI can be extracted have been identified, and in some cases elaborated ad-hoc. This preliminary information about the availability of datasets will play a major role in the activities to be carried out soon so the pilots will be prepared for the initial evaluation tasks.

The user stories and requirements have been also revisited in more detail to determine its scope and applicability in NARRATE, and its relationship with the technical solutions. To this last end, the technical partners have indicated the impact of their implementations in the generic requirements and the pilot-specific ones, so a preliminary mapping could be elaborated.

In addition to this, the next sections describe further relevant activities, such as the definition and analysis of early use cases, the elaboration of preliminary Blueprint examples for the early demonstrator, and the definition of the plan for the early demonstrator. This section also includes a short summary of the activities to be carried out further on regarding the WP5 activities.

6.1. EARLY USE CASES

To provide a more aligned and focused vision of the NARRATE outputs and the pilots' expectations, a set of use cases (UCs) has been defined. These UCs aim at covering the whole scope of the Blueprints information, and they can be considered cross-pilot cases so they can be executed by every pilot. Besides this, the UCs are contrasted with the raw list of requirements, obtaining a vision of the pilots' coverage provided by them.

Thus, the generated refined list of User Stories (USs) includes those straightforward and comprehensive stories that appropriately represent the pilot scenarios that also enable the tracking of the development across the three planned releases following a progressive and manageable approach.

6.1.1. Detecting a Delay in Raw Material Delivery

Through this case, the company identifies a delayed shipment and switches to an alternative supplier to prevent a production halt.

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The pilots directly involved in this UC for the early demonstrator are MEDWOOD, and BUDATEC.

The generic requirements addressed in this UC are:

- Warning and notification mechanisms (WN)
- Disruption monitoring (DM)
- Environmental management (EM)
- Project management (PJ)

Regarding pilot-specific User Stories, those addressed in this case are:

For the MEDWOOD pilot:

- MIC_03: evaluate different options for the supply of materials and services to select the most suitable ones
- MIC_07: receive warnings when some material has not arrived at the premises to update the plan accordingly
- MIC_17: find optimal suppliers when some supply disruption occurs based on decision parameters to select the most appropriate option
- MIC_24: keep the chain of custody PEFC certification for own products (acquire certified materials and track and trace them to acquire certified products)

For the BUDATEC pilot:

- BUD_05: receive a warning for non-certified parts
- BUD_16: get automated notifications in the event of potential project delays
- BUD_20: receive information about the delivery status of suppliers and send automated regular inquiries about the delivery date

It should be noted that, even considering that some preliminary user stories of the AIDIMME pilot are somehow aligned to the current UC, the AIDIMME pilot considers just a few suppliers (habitual ones) for the supply of materials, becoming not a critical aspect.

6.1.2. Predicting Machine Failure and Scheduling Maintenance

In this UC, the company detects potential machine failures in advance, with the aim of proactively scheduling the corresponding maintenance activities.

The pilots directly involved in this UC for the early demonstrator are AIDIMME, and BUDATEC.

The generic requirements addressed in this UC are:

- Simulation capabilities (SC)
- Warning and notification mechanisms (WN)
- Disruption monitoring (DM)
- Environmental management (EM)
- Analytical capabilities (AC)
- Project management (PJ)

Regarding pilot-specific User Stories, those addressed in this case are:

For the AIDIMME pilot:

- AID_16: get integrated information about the overall production process (e.g., real-time machine data, logs) to anticipate to manufacturing failures

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- AID_17: receive warnings when machine defects or issues in parts are detected during the quality control to perform rescheduling if needed and generate reports
- AID_18: gain awareness about machine breaks to take appropriate actions (e.g., rescheduling, outsourcing) accelerating the response ahead of these problems
- AID_24: gain awareness about the status of every work (e.g., done, postprocess, number of pieces produced) to improve the work management and keep the customer updated about the status of the job queue and the machine availability so that the client can be aware of the production capacity before requesting an order

For the BUDATEC pilot:

- BUD_23: obtain an overview of relevant resources (e.g., parts, employees, cars, service cars) for spontaneous service calls
- BUD_27: perform plannable service assignments to be automatically prepared by informing the customers and BUDATEC

6.1.3. Resolving Production Bottlenecks

In this UC, the company detects inefficiencies during the manufacturing, taking appropriate measures such as dynamically redistributing the workload.

All pilots are involved in this UC for the early demonstrator: MEDWOOD. AIDIMME, and BUDATEC.

The generic requirements addressed in this UC are:

- Warning and notification mechanisms (WN)
- Disruption monitoring (DM)
- Manufacturing management (MM)
- Analytical capabilities (AC)
- Production management (PM)
- Project management (PJ)

Regarding pilot-specific User Stories, those addressed in this case are:

For the MEDWOOD pilot:

- MIC_01: perform production simulations to check different options of execution plans
- MIC_06: predict the needs for capacity increase of machinery and workers to adjust resources based on future demand
- MIC_08: receive warnings when some product defect is found to adjust the production activities
- MIC_09: get notifications when some production order has not been manufactured
- MIC_11: obtain the optimal sequencing of manufacturing orders based on rules to select the most suitable one
- MIC_12: obtain the optimal sequencing of manufacturing orders based on rules when some problem occurs (e.g., broken machine) to select the most suitable one
- MIC_14: check the correct sequencing of manufacturing orders to take corrective actions
- MIC_16: get recommendations about the use of machinery to check energy consumption overload, determine the machinery to use, and update the information accordingly
- MIC_18: collect and analyse production-related data to perform improved decision-making and propose improvement measures

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- MIC_21: get notifications about deviations regarding the cycle time of the operational working centre and obtain proposals to take actions to meet the schedule

For the AIDIMME pilot:

- AID_02: foresee consumption of raw materials and consumables from historical data to prevent stockout
- AID_04: obtain traceability of the material feedstocks when a batch of material is received, storing batch Information to foresee possible issues in the raw material
- AID_05: gain awareness of the status of the warehouse of materials and spare parts to foresee the demand of resources
- AID_09: gain awareness about the status of the machines (e.g., downtimes, workloads, bottlenecks) to replan the build jobs in an optimal way
- AID_12: manage the work teams and assign tasks (e.g., postprocess, quality control, delivery) to improve the overall management of the work
- AID_13: gain awareness about the status of every work (e.g., done, in postprocess, number of pieces produced) to improve the work management
- AID_15: get support in the arrangement of build jobs to improve the production scheduling based on delivery terms

For the BUDATEC pilot:

- BUD_08: obtain a single view for performance measurements to inspect production times, and get a central error overview for production and commissioning clearly deriving improvements
- BUD_11: get feedback on the processes and products to continuously improve products and processes
- BUD_17: real-time project status tracking to recognize time and cost-relevant issues as soon as possible.

6.1.4. Mitigating Transportation Disruptions

Through this UC, the company detects transportation disruptions (e.g., traffic, weather conditions) and takes corrective actions, such as rerouting the deliveries.

The pilot directly involved in this UC is BUDATEC.

The generic requirements addressed in this UC are:

- Simulation capabilities (SC)
- Warning and notification mechanisms (WN)
- Logistics management (LM)
- Disruption monitoring (DM)
- Analytical capabilities (AC)
- Environmental management (EM)
- Sales and service tracking (ST)
- Project management (PJ)

Regarding pilot-specific User Stories, those addressed are from the BUDATEC pilot:

- BUD_06: real-time order monitoring to constantly check the status of the delivery
- BUD_07: obtain an overview of all transportation services

Some user stories from the MEDWOOD pilot are somehow aligned to the current case, but MEDWOOD does not manage the deliveries to end consumers specifically. The

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AIDIMME pilot is neither covered in this case, so the deliveries to customers from AIDIMME are abundant, close and relatively easy transportations.

It is worth noting that some of the generic requirements are shared by all the proposed: warning and notification mechanisms (WN), disruption monitoring (DM), and project management (PJ).

The actual list of use cases is just a first approach for the evaluation and analysis of the functionalities to be provided by the technical solutions. Additional use cases will be further defined to cover other relevant aspects for the pilots' environment, such as the management of sustainability information, and the warehousing. These use cases will be taken for the preparation of case scenarios to be applied in the evaluation and validation process by the pilots in the demonstrator.

6.2. SAMPLE BLUEPRINTS FOR DEMONSTRATION

The unique consideration of the MEDWOOD pilot for the definition of the proposed early demonstrator does not cover the entire scope of NARRATE (this can be also visualized through the coverage by the Blueprints). As an example, the Logistics Blueprint is oriented not to internal or supply logistics, but to the transportation to the end client, aspect that is not covered by the MEDWOOD pilot. Same applies to the sensor-related Blueprint.

Therefore, to provide a more comprehensive scenario, the proposed demonstrator not only considers the scope of MEDWOOD, but also the AIDIMME and BUDATEC pilots covering in this way the whole vision of NARRATE. The entities are framed in colours to depict the main pilot involved in the generation of each sample blueprint for the early demonstrator (MEDWOOD in red, AIDIMME in green, and BUDATEC in blue).

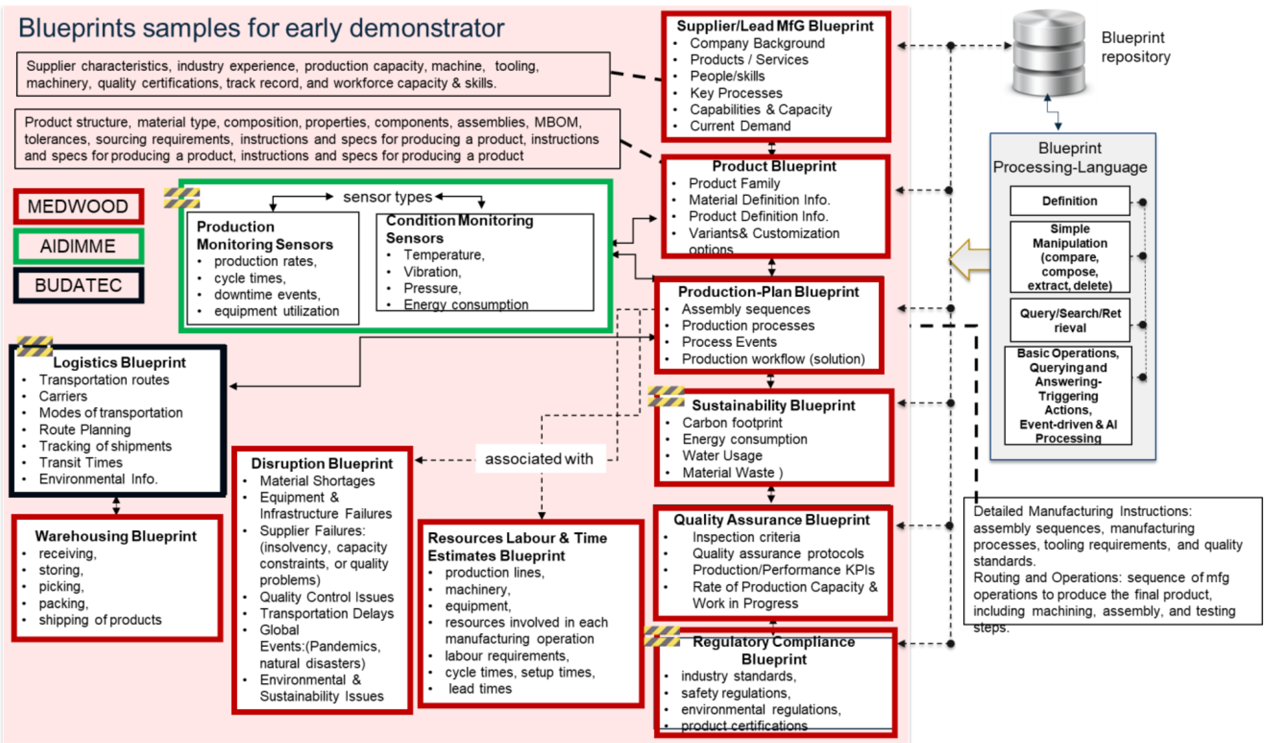

Figure 11: Blueprints covered by the early demonstrator involving all the pilots

A list of Blueprint samples is included in the Table 7 below. The structure of these examples follows the needs detected specifically in the MEDWOOD pilot.

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Product Blueprint (final product)

DEFINE PRODUCT CotMartha {
code: "MARTHA“
name: "CUNA DE 120X60 MARTHA ROBLE“
type: “Finished product“
level: “0"
quantity: “1“
unit: "Un"
weight: “30,7 Kg"
provider: null
material_family: null
material_subfamily: null
}

Product Blueprint (product part)

DEFINE PRODUCT PataMarthaHaya {
code: "C14662“
name: "PATA MARTHA HAYA DE 170 (NAT)“
type: “Raw material“
level: “2"
quantity: “4“
unit: "Uf"
weight: “0,4 Kg"
provider: “00087”
material_family: “C-TRABAJOS_EXTERNOS”
material_subfamily: “C-TRAB_EXT_PRODUCCIO”
}

Supplier Blueprint
DEFINE BLUEPRINT TYPE SUPPLIER TorneadosYMecanizadosDeMadera { code: "00087"

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```
    name: "N.I. EN TORNEADOS Y MECANIZADOS DE MADERA, S.L."
    location_street: "C/ ACEQUIA REAL DEL JUCAR, 66"
    location_zipcode: "46460"
    location_town: “SILLA"
    location_province: “VALENCIA"
    location_region: “COMUNIDAD VALENCIANA"
    location_country: “España"
    number_deliveries: “745"
    number_delays: “67"
    percentage_delays: “8,99"
    evaluation_actual: “A"
    evaluation_previous: “B"
    percentage_ontime_deliveries: “93,98"
    average_delay_time: “35,4"
    pending_deliveries: “6,02"
    average_delivery_lead_time: “2,13“
    road_transport_distance: “17 Km“
    sea_transport_distance: “0 Km”
    air_transport_distance: “0 Km“
    distance_from_client: “17 Km“
}
```

Warehousing Blueprint

```
DEFINE BLUEPRINT TYPE WAREHOUSING PataMarthaHayaWH {
    code: "C14662"
    ordered_quantity: "996"
    warehouse: “null"
    delivery_date: "06/11/2024 “
    quantity_other: “996"
    location: “MC"
    stock: “104“
```


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```
    total_ordered: null
    minimum_stock: "0"
    order_date: "06/11/2024 "
    requested_date: null
    pallet_quantity: null
    unit: "Uf"
    supplier: null
    minimum_quantity: "0"
    total_available: "-996"
}
```

Process Blueprint

```
DEFINE BLUEPRINT TYPE PROCESS sanding {
    code: "OP_PUCUNAS"
    name: "OPERARIOS PULIMENTO CUNAS"
    type: "Operario"
    operation: "OP_CABTINM"
    level: "2"
    quantity: "0,016"
    estimated_rhythm: "62,5"
    unit: "Hours"}
```

Resources Labour & Time Estimates Blueprint

```
DEFINE BLUEPRINT TYPE PROCESS boothDYN {
    code: "CABINAFCUN"
    date: "09/01/2024"
    production_code: "P23020991"
    work_code: "23000336244"
    work_center: "CABINA FONDO O TINTE DE TESTAS PULIMENTO CUNAS"
    finished: "SI"
    number_workers: "1"
    worker_time_estimated_by_order: "1,6"
```


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worker_time_estimated_by_piece: "1,20" worker_time_reported: "1,52" machine_time_estimated: "1,2" machine_time_reported: "1,52" number_pieces_estimated: "400" number_pieces_reported: "300" number_bad_pieces: "0" number_good_pieces: "300"}
Production Plan Blueprint
DEFINE BLUEPRINT TYPE PRODUCTION_PLAN CotMarthaProductPlan { step1: REQUEST TorneadosMecanizadosMadera.material IF inventory_check(pataMarthaHaya170) < 2 step2: EXECUTE DyingBoothStage step3: EXECUTE BottomBoothStage AFTER DyingBoothStage step4: EXECUTE SandingStage AFTER BottomBoothStage step5: EXECUTE FinishingBoothStage AFTER SandingStage step6: REQUEST MaderasMartinezJurio.material IF inventory_check(PiecerioHaya620x45x26) < 4 step7: REQUEST TorneadosMecanizadosMadera.material IF inventory_check(tablillaSinMuldurar) < 22 step8: EXECUTE WeiningMolduing step9: EXECUTE TurningStage (from SUBCONTRACTOR) step10: EXECUTE LateralCenterStage step11: EXECUTE PackingStage}
Disruption Blueprint
DEFINE BLUEPRINT TYPE Disruption { event_code: "6" user: "Jorge García" role: "IT" rd_code: "IRD10" name: "Unplanned/corrective maintenance on IS/DSS"

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```
    date: "01/10/2024"
    description: "Central information system crash, paralyzing ERP"
    duration: "2 hours"
    impact_lost_sale: ""
    impact_defect_rate: ""
    impact_customer_satisfaction: ""
    impact_delay: ""
    impact_social: "low"
    impact_cost: "medium"
    impact_environmental: ""
}
```

Quality Assurance Blueprint

```
DEFINE BLUEPRINT TYPE QualityAssurance {
    date: "16/12/2024"
    sanding: ""
    caragolillo: " "
    chorrera: ""
    hit_scratches: ""
    dirt_contamination: "26"
    cracks: ""
    textured_black: ""
    total_defects: "26"
    repaired: ""
    reprocessed: "26"
    rejected: ""
    reviewed: "73"
    machine_time_theo: ""
    machine_time_reported: ""
    number_pieces_theo: ""
    number_pieces_reported: ""
```


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```
bad_pieces: “”
good_pieces: ““
resource: ““}
```

TABLE 7: BLUEPRINT SAMPLES FOR THE MEDWOOD PILOT

These blueprint samples were produced taking a furniture piece of MEDWOOD as a product example (the cot Martha) and its components (e.g., legs, lateral sides, packing), suppliers (e.g., pieces, paintings), and processes (e.g. polishing, dyeing). This information was generated from the breakdown of such piece of furniture but also gathering information from Excel files generated from the ERP. These files include information about the involved processes, suppliers, quality issues, etc.

For disruptions information, a template (risk disruption matrix) provided by the technical partners was fulfilled and used to generate the corresponding blueprint sample.

The sustainability information, as previously stated, requires further iterations to be completely defined. In this regard, the inclusion of additional attributes in existing blueprints is considered. As an example, the distance-related attributes that can be found in the supplier blueprint are particularly relevant to later conduct calculations related to the carbon footprint generation.

The diagram in FIGURE 12 below shows an excerpt of a relationship diagram of entities representing the first version of the blueprints example generated for the early demonstrator.

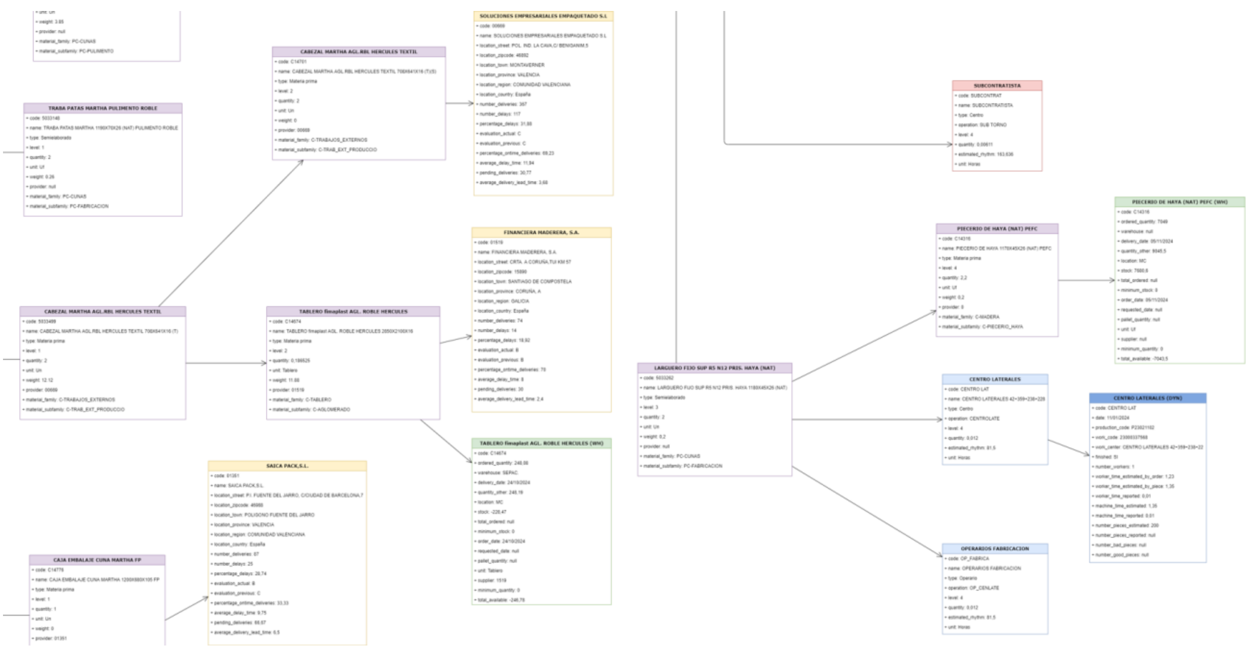

Figure 12: Excerpt of diagram of blueprint entities for a sample product of MEDWOOD

The colours of the entities in FIGURE 12 represent the type of blueprint that represents such entity. Products and components in purple, suppliers in yellow, raw materials in green, processes and resources in clear and dark blue respectively, and outsources processes in red. The relationship diagram was generated not from the entire breakdown of the

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selected product, but from a simplified version including some of the most important items. This diagram can be found in the annex.

Samples for sustainability, regulatory compliance, sensor-type and logistics blueprints will be generated from the pilots to provide a comprehensive example of the information managed in the industrial environments.

Also, the structure of the presented blueprints may vary to adapt to the particularities of the other pilots and their needs.

6.3. EARLY DEMONSTRATOR PLAN

The MEDWOOD pilot has been selected as early pilot demonstrator due to the prompt availability of data sources and schemas as well as the overall scope covered at production level.

As already commented in this report, the proposed demonstrator not only considers the MEDWOOD but also the AIDIMME and BUDATEC pilots covering the entire vision of NARRATE.

The next Figure 13 shows the proposed workplan based on the Technology Roadmap, aiming at providing a simplified and clear vision of the timing for the availability and the implementations and the conduction of validation activities.

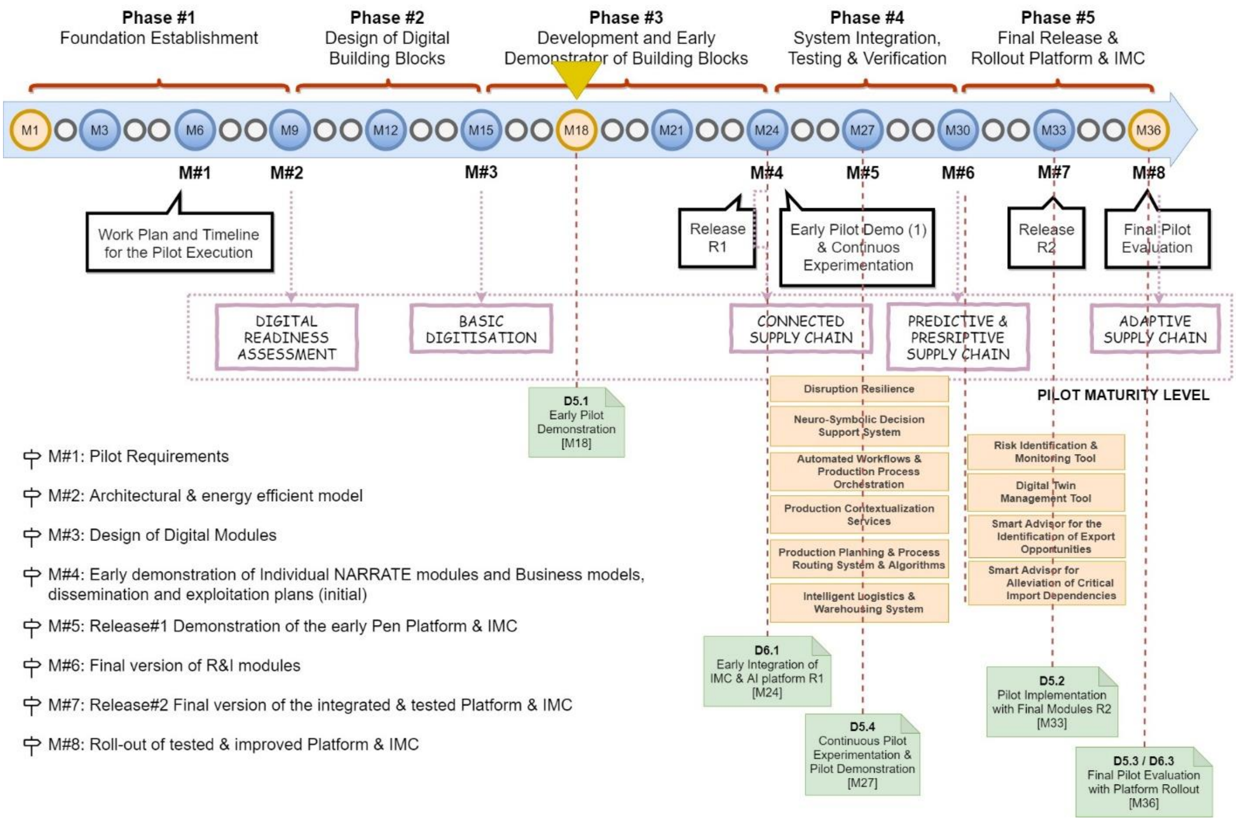

Figure 13: Workplan based on the NARRATE technology roadmap

As can be seen in Figure 13 , most of early versions of the technical solutions are expected to be available in M24, when the early integration of IMC and AI platform (R1) is accomplished. In M27, the results of the continuous pilot Experimentation and

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demonstration will be presented. Later in M33, the pilot implementation with the final modules is expected to be available, and its final evaluation to be reported by M36.

The set of methodological resources expected to be used in the validation process should be reminded.

On the one hand, the Requirement Traceability Matrix (RTM) approach is proposed as a traceability system for developers and users to track the requirements and monitor its adequate fulfilling, keeping all the actors aware of the implementation process. The RTM can be used to validate that every requirement is checked trough the test cases (TCs) to guarantee that every functionality has been properly tested during the validation phase.

On the other hand, the User Acceptance Testing (UAT) allows a detailed test of the expected functionalities by the end users, determining the level of acceptability of the implementations. To address a proper testing process, after defining a preliminary test plan, the scope of the UAT should be determined in terms of functionalities and then define the specific test cases to conduct the validation and finally evaluate the results. These results are analysed to take the required corrective actions, perform an additional testing, and then release a new version of the corresponding implementation.

7. CONCLUSIONS

This document D5.1 has made a review of the specific and generic KPIs of the three pilots taking into account the scope of NARRATE, since at the beginning the end users raised desired situations, but not possible to address in NARRATE.

A review of the technical solutions to be implemented has been carried out, but from a functional point of view, not a technical one, with the idea of having a vision of what each solution is going to offer for the early demonstrator, considering the reference architecture. We have worked closely with the technical partners (responsible for each solution), to see the approach and prepare an evaluation plan of the solutions depending on when they will be available according to the NARRATE Technology Roadmap.

It has been defined which Blueprints can be addressed in each pilot, covering the part of manufacturing processes mainly in MEDWOOD´s pilot, the part for IoT in AIDIMME´s pilot and the part of logistics in BUDATEC´s pilot, although the Blueprints of production, product, sustainability, resources, disruptions will also be addressed but in the demonstrator it will be MEDWOOD first.

Some Use Cases have been defined to make the developments easier to focus on the problem by instantiating an example of a cradle, as well as to raise a plan for the early demonstrator. As the project progresses, the solutions will be validated with the datasets provided by the users in a confidential manner to validate the solutions according to the answers provided by the IMC. The technical solutions will be refined as users test them so that developers can improve them for future releases. It is joint work between developers and users. This is the key to being able to have efficient solutions that really respond to the problems that arise in supply chain and manufacturing processes and be as resilient as possible.

The activities to be carried out in the new future in the scope of the early pilot demonstrator can be classified into two main matters.

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The early integration of the solutions is expected to be available in M24, leading to the release #1 with all the available tools integrated with the IMC. To this end, the hosting is planned to start in M22, ensuring the readiness of the overall architecture (including servers) and the required installations of software.

Then the IMC will be installed as well as those technical solutions that could be ready for internal testing at that time. In M23, the integration of solutions should be ready for testing, and incidents will be addressed (e.g., solving of incidents, code fixing, implementation of required APIs, etc.). At this point, a plan for biweekly releases of new versions of the solutions and the corresponding testing will be arranged.

In M24, it is expected the continuation of the addressing of incidents of any kind, and no initial installations should be expected. Also, a plan for biweekly releases for new versions of the technical solution and testing will be prepared. At such stage, the release #1 of the platform is expected to be ready.

In the meantime, the completion and refinement of blueprint will be conducted, with the specific involvement of the AIDIMME pilot for the IoT-related information for the sensor-type blueprint, the involvement of BUDATEC for the logistics blueprint, and the main involvement of MEDWOOD for the sustainability-related blueprints.

Additional use cases will be defined to cover more relevant aspects for pilots, such as the management of sustainability information and logistics. Furthermore, case scenarios from the use cases will be prepared to address the evaluation and validation process to be carried out by the pilots.

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8. APPENDIX

This annex contains complementary information for this deliverable.

ID	Description of requirement
SIMULATION CAPABILITIES	
SC_1	Manufacturing simulation that includes manufacturing plans and sequences, adapter to plant stimulation, visitable (layout planning software), etc.
SC_2	Ability to create simulations of fictional disruptive scenarios through adjusting different parameters.
SC_3	Results representation from implemented simulations and analysis of th e data derived from the simulations.
SC_4	Analysis of the disruptive scenario and suggestions for manufacturing and resilience improvement
WARNING AND NOTIFICATION	
WN_1	Alert system which functions via pre-defined thresholds and ability to change those thresholds.
WN_2	Real time monitoring of machine functions with live machinery data and instant alert capabilities.
WN_3	Automatic or manual upload (through technician) notification of machine disfunctions, disruptions and downtimes to all involved parties (production management, logistics management, manufacturing management)
WN_4	instant notification of production orders and/or product deviation to all involved parties (production management, logistics management, manufacturing management)
WN_5	Notification system for disruptions or changes in supplier transportation

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WN_6	Predictive warnings for possible stockout, discrepancies between current and historical production data and differences between planned and current project work.
WN_7	Notification to all involved parties of changes made to parts, manufacturing orders and discrepancies on quality control.
LOGISTICS MANAGEMENT	
LM_1	Real time monitoring of delivery status (tracking, delivery dates, shipped products) with automatic request for information update by the supplier.
LM_2	Automated comparison of scheduled and real delivery status with instant deviation and/or delay notification to all the parties involved (logistics, manufacturing, SCM)
LM_3	Overview of all transportation partners and their delivery status (tracking, delivery dates, parcel traceability) , as well as their carbon footprint on each parcel transportation to choose the best option or offer different alternatives that suits the customer needs.
LM_4	interface for easy access of different information (historical data, tracking, carbon footprint, delivery notes) and overview of delivery status.
DISRUPTION MONITORING	
DM_1	Platform for managing internal and external disruptions (environmental, social, political, customer/supplier, etc.) under predefined rules with automated updates and real time monitoring.
DM_2	Analysis and suggestions for preventive actions against disruptions on the supply chain (usage of historical data, internal data, market trends, planned and current workloads, etc)
DM_3	Alert system for possible and current disruptions/deviations with the information provided by the customer/supplier and internal data.
MANUFACTURING MANAGEMENT	
MM_1	Real time monitoring and overview of current and future manufacturing plans with automated or manual updates.
MM_2	Overview of manufacturing sequences established by predefined criteria. (delivery dates, machine downtimes, etc.)
MM_3	interface for managing parts related data (materials, 3D prints, data sheets, technology, quantity, etc.) with manual and automated

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	uploads based on historical data, customer information, supplier information and internal data.
ANALYTICAL CAPABILITIES	
AC_1	Analysis of current transportation routes and suggestions for alternative transportation methods (decentralized transportation/production, different routes, etc.) based on predefined parameters (costs, time, carbon footprint, routes, rates per kg, etc.)
AC_2	Analysis of current contracted suppliers and generation of alternative suggestions based upon predefined thresholds (costs, product quality, delivery time, etc.)
AC_3	Analysis of the scenarios generated by the simulation capabilities of the IMC.
AC_4	Analysis of different current scenarios regarding predefined KPI's and optimization proposals (minimize machine use time, prioritize larger orders, minimize delivery times, prioritize orders of some references, manufacturing cost, delivery time, etc.)
AC_5	interface for results overview and evaluation of analysis made.
AC_6	Forecast of project development and/or project disruption based on internal and external data (historical data, seasonal fluctuations, workloads, machine capacity, order queues, etc.) and optimization suggestions.
AC_7	Visualization, analysis and suggestions on quality control based on pre-defined thresholds (historical data, quality incidents, supplier information, customer feedback, etc.)
PRODUCTION MANAGEMENT	
PM_1	Overview and real time monitoring of production machines (workloads, orders in progress, etc.)
PM_2	interface for visibility of production orders overview with automatic synchronization and dynamical adjustments features
PM_3	interface for production planning, task assignment, employee management and project overview.
PM_4	Overview of supply chain and projects status and connections between them including supplier information, warehouse status, machine operations, etc.
PM_5	integration of current software and ERPs.

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ENVIRONMENTAL MANAGEMENT	
EM_1	interface for overview and display of environmental information of pro ducts. input (from supplier) and output (for customer).
EM_2	interface for waste tracking, management and optimization suggestions (display of waste generation through failures, waste per production order, companies with waste as raw material, industrial symbiosis, etc.)
EM_3	Tracking and overview of product parts and materials certifications predefined points (percentage of renewable materials, carbon footprint, etc.)
EM_4	Display and overview of environmental factors among the supply chain, regarding predefined thresholds and KPIs and opportunities for improvement.
EM_5	Suggestions for better environmental practices regarding predefined thresholds (energy consumptions, supplier information, carbon footprint, seasonal fluctuations, weather forecasts, etc.)
SALES AND SERVICE TRACKING	
ST_2	Display of current customers and products, potential new customers and facility to manage new offers made.
PROJECT MANAGEMENT	
PJ_1	Prediction and notification of delays on ongoing projects by predefined parameters (delivery dates, manufacturing orders, machine downtimes)
PJ_2	Real time monitoring and tracking of project status through supplier information upload and internal data.
PJ_3	Overview of parties involved on the project and access to project information.

ANNEX 1: DESCRIPTION OF GENERIC REQUIREMENTS (AFTER DISCARD PROCESS)

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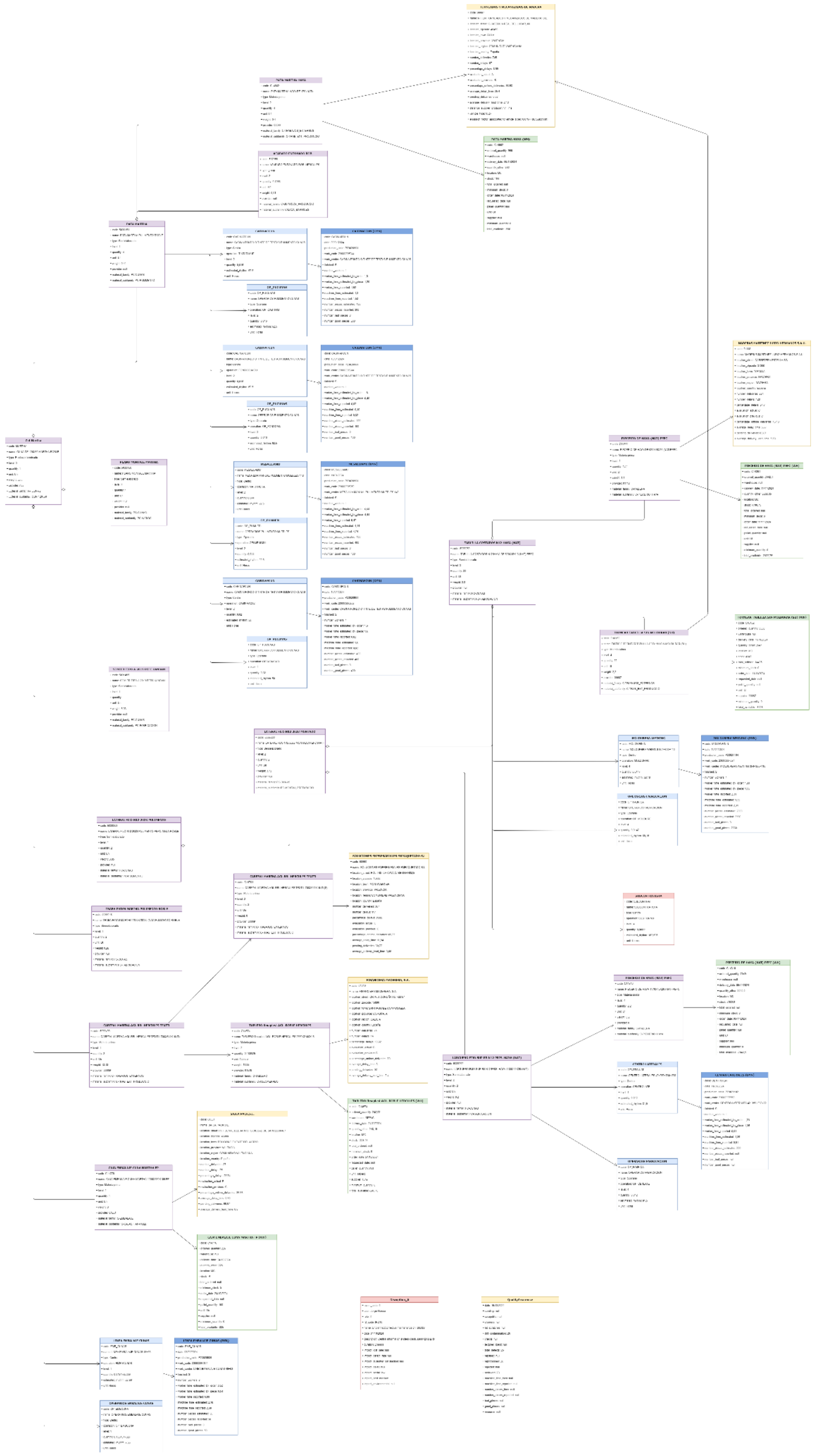

ANNEX 2: DIAGRAM OF ENTITIES AND RELATIONSHIPS FOR THE MEDWOOD BPS EXAMPLE

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