D4.3

EUR3KA R3 Cognitive Digital Twin Services – First release

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Reviewers' Comments and Relevant Revisions

Comment	Revision
The status of implementation should be presented in a table	Table 4 provides the descriptions of the implementation status for each technology/result
More detailed information in terms of quality control checks, data format is quite an issue. Management of such data transformation is insufficiently considered in the document	More details are provided in the sections 4.2 and 5.2
The lifecycle of the cognitive digital twin should be demostrated	Dedicate sections 6.4 and 6.4.1 for cognitive digital twin have been added
The usage of AI should be explained	The usage of AI is demanded to sections 5.3 and 5.4, providing also a concrete example of its usage in the SEAC pilot

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Role	Date	Who	Approved/Comment
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Executive Summary

The main mission of the Eur3ka project is to build and validate a plug and response platform that will enable manufacturers to respond to the challenges arising from the COVID19 healthcare crises and related future events that could disrupt production operations. The platform will address the most important challenges faced by manufacturers: the need to operate their plants despite COVID19 measures and restrictions, the need to address disruptions in the Supply Chain, the need to design new, as well as the need to certify the products in-line with applicable regulatory requirements. To make this happen, the Consortium partners are involved in the development of a pool of services for manufacturing response for the optimisation of cross-sectorial supply network, the development of services for assessment of supply chain resilience, for smart matching and mediation services, that is a kind of smart search engine to match medical product manufacturing specifications and Eur3ka manufacturing network resources, to provision production continuity in terms of advanced AI-powered data driven decision support services for risk and the social distancing virtual assessment for virtual repurposing and commissioning, to extend the manufacturing equipment for remote and connected operation. An early deployment of Eur3ka platform R3 Service Platforms and Infrastructures has been already done as reported in D3.1, in an environment where trusted data sharing and manufacturing and repurposing capabilities information profile is guaranteed.

This document describes which is the current status of the development of the services, mapped toward the Eur3ka Reference Architecture defined in D2.1 (2), representing the main pillars of the 4 Grand Scenarios introduced in D3.1. The outcomes, considering also the technical enablers defined such as the supply chains cooperation and coordination for manufacturing repurposing, will support the Eur3ka network for the technical validation, experimentation and on-site trials. The final results will be defined in the next months, useful also for the refinement of fast manufacturing and logistic/supply chain repurposing services specifications.

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Definitions and acronyms

AI	Artificial Intelligence
AMN	Additive Manufacturing Network
CA	Consortium Agreement
CI/CD	Continuous Integration /Continuous Development
CPFR	Collaborative Planning Forecast and Replenishment
CPS	Cyber Physical Systems
DoA	Description of Action
DQC	Digital Quality Control
EC	European Commission
EU	European Union
GA	Grant Agreement
ICT	Information and Communication Technologies
IDS	International Data Spaces
IDSA RA	International Data Spaces Association Reference Architecture
IoT	Internet of Things
IT	Information technology
MES	Manufacturing Execution System
PPE	Personal Protection Equipment
PC	Project Coordinator
QMS	Quality Management System
SCADA	Supervisory Control and Data Acquisition
SCSN	Smart Connected Supplier Network
SMMA	Smart Matching and Mediation Application
TC	Technical Coordinator
UBL	Universal Business Language 2.1
WP	Work Package
ZDM	Zero Defect Manufacturing

1 Introduction

1.1 Scope and Purpose

Starting from the beginning of 2020, the COVID19 pandemic affected the production operations and supply chains, so that for many companies the demand for some products was significantly reduced, but at the same time, there was an increasing demand for other products like face masks and sanitizers and so on.

At that time many manufacturers repurposed their production analysing their supply chain operations in order to support the new requirements. The willingness to have an agile and flexible production become a must against future disruptions.

Eur3ka will boost the agility and flexibility of the manufactory chains for any kind of unforeseen future. The present deliverable is destined to provide an outline of the early deployment of the Eur3ka provided services defined as:

- Resilient Smart Supply Networks Services
- Robust On-demand Manufacturing Networks
- Rapid Reconfiguration & Production Line Continuity
- Reliable Repurposing of Production Line Services

The WP4 tasks, where the development of the technical enablers defined in WP3 (smart matching & mediation, interoperable sovereign data sharing spaces, plug & respond modular digital manufacturing lines, AI-powered cognitive digital twins and just-in-time just-in-place training) is ongoing, will support the operation of the Eur3ka platform and associated services with the scope of satisfying experiments needs as required in WP5. About the deployment and use of AI/ML in manufacturing repurposing scenarios is currently very challenging due to the lack of appropriate datasets from past disruptions of production and shocks in the supply chain. Nevertheless a prominent example is provided, reported in section 5.4, as ML module training (neural network) for automatically identifying and specifying repurposed product configurations in the SEAC face masks pilot. The development of the neural network will accelerate the quality testing process, while driving the extraction of knowledge on which parameters are likely to lead to products of acceptable quality. WP4 will provide two releases of the Eur3ka platform services. Moreover, it creates a direct link with the Reference Architecture defined in D2.1 to figure out a practical mapping among its blocks and the services currently developed (see chapter 2). This deliverable depicts a snapshot of the progress done until M12 and it could be a starting point to the refinement of services definition.

1.2 Structure of the document

The deliverable is structured as follows:

- Section 2 describes how the Eur3ka services are mapping the Reference Architecture building blocks.
- Section 3 focuses on the optimisation and alignment of cross-sectorial supply network, the development of services for assessment of supply chain resilience.

These services should enable agile supply chains in order to dynamically configure them based on the available production capabilities.

- Section 4 describes the development of smart matching & mediation services, that is a kind of smart search engine to match medical product manufacturing specifications and Eur3ka manufacturing network resources.
- Section 5 defines the provisioning of production continuity services in terms of advanced AI-powered data driven decision support services for risk and the social distancing virtual assessment for virtual repurposing and commissioning.
- Section 6 points to the development of extensions to manufacturing equipment for remote, connected operation. A digital manufacturing solution for flexible manufacturing automation and products for complex ventilator manufacturing will be discussed.
- Section 7 is the last and concluding section of the deliverable. It draws main conclusions and provides an outlook for future developments.

1.3 Revision of the Deliverable following Reviewers' Comments

The current version of the deliverable is revised to address comments and suggestions about improving the quality of the deliverable that were received following the technical review of the Eur3ka project by the European Commission on May 5th, 2022. Specifically, in this version of the deliverable the consortium has included the status of implementation for technologies and results presented in a table, detailed information for quality control checks, data format, data transformation insufficiently considered previously, such as the lifecycle of the cognitive digital twin demostration and the usage of AI. This information has been provided in an updated version of section properly reported in "Reviewers' Comments and Relevant Revisions" table.

2 Mapping among EUR3KA RA blocks and services

Manufacturing repurposing transformations comprise multiple dimensions, including production repurposing, supply chain flexibility, business continuity and manufacturing on demand. These dimensions span functionalities both inside the factory and across the manufacturing value chain. To support the implementation of manufacturing transformation across these dimensions, Eur3ka leverages the concept of a digital twin towards modelling different production processes and supply chain processes. Specifically, the project collects and manages digital information about production facilities and processes concept all of the above listed dimensions. This information is managed as a digital twin of the manufacturing environment. The information of the digital twin is processed to drive the definition and implementation manufacturing response processes that respond to large scale disruptions of production due to events like problems in supply chain operations, the need to operate with reduced workforce, as well as the need to repurpose production towards new products. These responses incrorporate intelligence at the level of reconfigurable processes (e.g., shifts allocation, virtual training) and trusted supply chains (e.g., sharing of product digital models to support 3D printing). Therefore, the Eur3ka digital twin is characterized as a "Cognitive Digital Twin", due to its intelligence and the ability to continually learn and improve the quality of its response. Not however the Eur3ka digital twin does not directly incorporate elements of cognitive science, like the digital twins in recent research works[1].

In this context the Eur3ka RA specifies the structuring principles of a cognitive digital twin for manufacturing repurposing, along with elements for realizing it. In the table below there is a mapping among RA blocks and the services currently developed, considering the status of progress until M12. This mapping allows to better understand all the EUR3KA Platform features can be used in a company to repurpose its supply chain and support the new requirements. The services mentioned are described in D3.1 and in the following sections, in D3.2 there will be a refinement and improvement of them in order to facilitate and better support their integration in WP5 trial.

Table 1 - Mapping among EUR3KA RA blocks and services

RA block	D3.1 and D4.3 services
Supply Chain Transparency Services	Smart Connected Supplier Network (SCSN)
Smart Mediation & Matching Services	Smart Factory Web Smart Matching and Mediation Application (SMMA)
Production Quality Control Digital Workspace	M3 MiWorkspace platform
Digital Workplace (AI)	Digital Twin / AAS
Business Continuity Framework	Smart Shift Allocation System

[1] M. A. Al Faruque, D. Muthirayan, S. -Y. Yu and P. P. Khargonekar, "Cognitive Digital Twin for Manufacturing Systems," 2021 Design, Automation & Test in Europe Conference & Exhibition (DATE), 2021, pp. 440-445, doi: 10.23919/DATE51398.2021.9474166.

Risk Assessment Services	Connecteam (https://connecteam.com/) mHelpDesk (https://www.mhelpdesk.com/) Shiftboard (https://www.shiftboard.com/) TSheets (https://www.tsheets.com/) Homebase (https://joinhomebase.com/) Deputy (https://www.deputy.com/) StaffJoy (https://www.staffjoy.com/) Risk Assessment Tool
Repurposed Production Line Virtual Commissioning	Virtual Components 4.0 3D Engineering & Simulation Platform for Pharma & Medical Production Systems.
Resilient Supply Chain Design Tools	Smart Connected Supplier Network (SCSN) Additive Manufacturing Network (AMN)
Flexible Production Line Design	Robotics Cells – Virtual Manufacturing – AR/VR 3D Printing - Additive Manufacturing (AM) Supply Chain Management Platforms
Quality Control Design Tools	ZDM Platforms Quality Management System
Production Repurposing & Resiliency Maturity Assessment Services	Production Repurposing Business Proximity Assessment Framework
Rapid Manufacturing Response Demand Activation Services	Innovation Catalogue & Solution Composer Stakeholder Qualification & Marketplace
Resilient Repurposing Offer Certification Services	Q-Health Q-Digital Automation
Technical building blocks for EUR3KA DS	IDSA Data Sovereignty, Identity Management Services

3 Resilient Smart Supply Networks Services

This chapter introduces the concept of supply chain collaboration by information sharing, by providing a generic introduction to this topic by providing a theoretical background and interview for insights from high-tech manufacturers. Subsequently a collaboration service is described to provide more agility to supply chains.

Background

Supply chain resilience describes a supply chain prepared for unexpected disruptions and is able to respond, recover quick, and emerge stronger after the disruptive event happens [1]. Supply chain resilience is however based on the assumption that not every risk is preventable. Therefore, it is focused on the adaptive capabilities of organizations to prepare for unexpected disruptions, respond to them quickly, and recover from them by maintaining operations at the desired level.

Figure 1 - Background for Resilient Smart Supply Networks

There are some conceptual differences within the literature regarding the mechanisms that contribute to supply chain resilience. According to Christopher and Peck (2004) [2] there are four key principles that contribute to supply chain resilience, namely: (1) Supply chain (re) engineering, (2) supply chain collaboration, (3) agility and (4) creating a supply chain risk management culture. Factors such as efficiency, flexibility, redundancy, velocity, and visibility were considered secondary factors.

However, according to Sheffi and Rice (2005) [3] supply chain resilience can be realized by (1) redundancy, (2) flexibility, and (3) change in corporate culture. In 2015 however, Sheffi argues that factors like collaborative relationships with suppliers (and other parties), standardization and modular design can help create a robust supply chain. Pettit et al. (2010) [4] developed a conceptual framework that include factors as the basis for implementation of supply chain resilience.

See the framework in Figure 2 below:

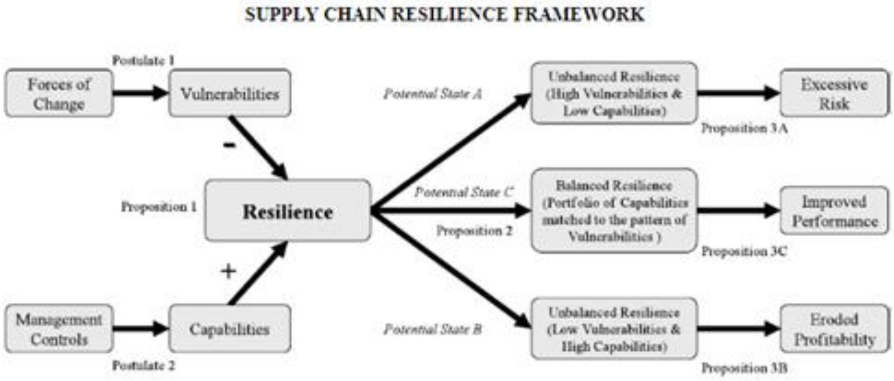


Figure 2 - Supply chain resilience framework

These factors are based on seven vulnerability factors and 14 capability factors.

The following seven vulnerability factors have been identified and thoroughly researched.

VULNERABILITY FACTORS

Vulnerability Factor	Definition	Sub-Factors
Turbulence	Environment characterized by frequent changes in external factors beyond your control	Natural disasters, Geopolitical disruptions, Unpredictability of demand, Fluctuations in currencies and prices, Technology failures, Pandemic
Deliberate threats	Intentional attacks aimed at disrupting operations or causing human or financial harm	Theft, Terrorism/sabotage, Labor disputes, Espionage, Special interest groups, Product liability
External pressures	Influences, not specifically targeting the firm, that create business constraints or barriers	Competitive innovation, Social/Cultural change, Political/Regulatory change, Price pressures, Corporate responsibility, Environmental change
Resource limits	Constraints on output based on availability of the factors of production	Supplier, Production and Distribution capacity, Raw material and Utilities availability, Human resources
Sensitivity	Importance of carefully controlled conditions for product and process integrity	Complexity, Product purity, Restricted materials, Fragility, Reliability of equipment, Safety hazards, Visibility to stakeholders, Symbolic profile of brand, Concentration of capacity
Connectivity	Degree of interdependence and reliance on outside entities	Scale of network, Reliance upon information, Degree of outsourcing, Import and Export channels, Reliance upon specialty sources
Supplier/Customer disruptions	Susceptibility of suppliers and customers to external forces or disruptions	Supplier reliability, Customer disruptions

Figure 3 - Vulnerability factors

Accompanied the following 14 capability factors have been identified and thoroughly researched.

CAPABILITY FACTORS

Capability Factor	Definition	Sub-Factors
Flexibility in sourcing	Ability to quickly change inputs or the mode of receiving inputs	Part commonality, Modular product design, Multiple uses, Supplier contract flexibility, Multiple sources
Flexibility in order fulfillment	Ability to quickly change outputs or the mode of delivering outputs	Alternate distribution channels, Risk pooling/sharing, Multi-sourcing, Delayed commitment, Production postponement, Inventory management, Re-routing of requirements
Capacity	Availability of assets to enable sustained production levels	Reserve capacity, Redundancy, Backup energy sources and communications
Efficiency	Capability to produce outputs with minimum resource requirements	Waste elimination, Labor productivity, Asset utilization, Product variability reduction, Failure prevention
Visibility	Knowledge of the status of operating assets and the environment	Business intelligence gathering, Information technology, Products, Assets and People visibility, Information exchange
Adaptability	Ability to modify operations in response to challenges or opportunities	Fast re-routing of requirements, Lead time reduction, Strategic gaming and simulation, Seizing advantage from disruptions, Alternative technology development, Learning from experience
Anticipation	Ability to discern potential future events or situations	Monitoring early warning signals, Forecasting, Deviation and Near-miss analysis, Contingency planning, Preparedness, Risk management, Business continuity planning, Recognition of opportunities
Recovery	Ability to return to normal operational state rapidly	Crisis management, Resource mobilization, Communications strategy, Consequence mitigation
Dispersion	Broad distribution or decentralization of assets	Distributed decision-making, Distributed capacity and assets, Decentralization of key resources, Location-specific empowerment, Dispersion of markets
Collaboration	Ability to work effectively with other entities for mutual benefit	Collaborative forecasting, Customer management, Communications, Postponement of orders, Product life cycle management, Risk sharing with partners
Organization	Human resource structures, policies, skills and culture	Learning, Accountability and Empowerment, Teamwork, Creative problem solving, Cross-training, Substitute leadership, Culture of caring
Market position	Status of a company or its products in specific markets	Product differentiation, Customer loyalty/retention Market share, Brand equity, Customer relationships, Customer communications
Security	Defense against deliberate intrusion or attack	Layered defenses, Access restrictions, Employee involvement, Collaboration with governments, Cyber-security, Personnel security
Financial strength	Capacity to absorb fluctuations in cash flow	Insurance, Portfolio diversification, Financial reserves and liquidity, Price margin

Figure 4 - Capability factors

What stands out is that the following supply chain resilience factors keep recurring in all researches: (1) redundancy, (2) efficiency, (3) flexibility / agility, (4) collaboration, (5) velocity and (6) visibility. It is clear, that when time moves on, some of these factors change and it would be better to take a look at how supply chains can actually build resilience.

The following insights have been obtained: (1) Build resilience by segmenting and/or regionalizing supply chains, (2) limit losses in performance by decentralizing the resources, and (3) overestimating the disruptive risks result in better decisions and is more profitable than not investing enough. By focusing on these three main objectives, organizations will minimize risk while also improving supply chain efficiency and limiting the impact on supply chain cost efficiency. Collaborative planning, forecast and replenishment (CPFR) is a business practice that enhances the integration of supply chains, by sharing information between the different supply chain partners. CPFR is a strategy that enables organizations in the supply chain to work together to increase sales and profit by improving forecasts and reduce inventory.

3.1 The Importance of Collaboration within Supply Chains

Literature highlights almost always the importance of collaboration within supply chains to ensure more resilience against external and internal disruptions. Supply chain collaboration involves the capability of two or more organizations to work together efficiently, by planning and executing supply chain operations to common goals. Compared to a soloistic approach, this creates more benefits in the long run. It relates to different organizations engaging in collaborative activities, such as: Information sharing, decision synchronization (following each other's decisions), resource-sharing and collaborative communication[9]. This is required to prepare an adequate response and recover from supply chain disruptions while reducing the impact of disruptive events. Collaborative communication is the way supply chain partners communicate with each other in terms of frequency, direction, mode, and influence strategy.

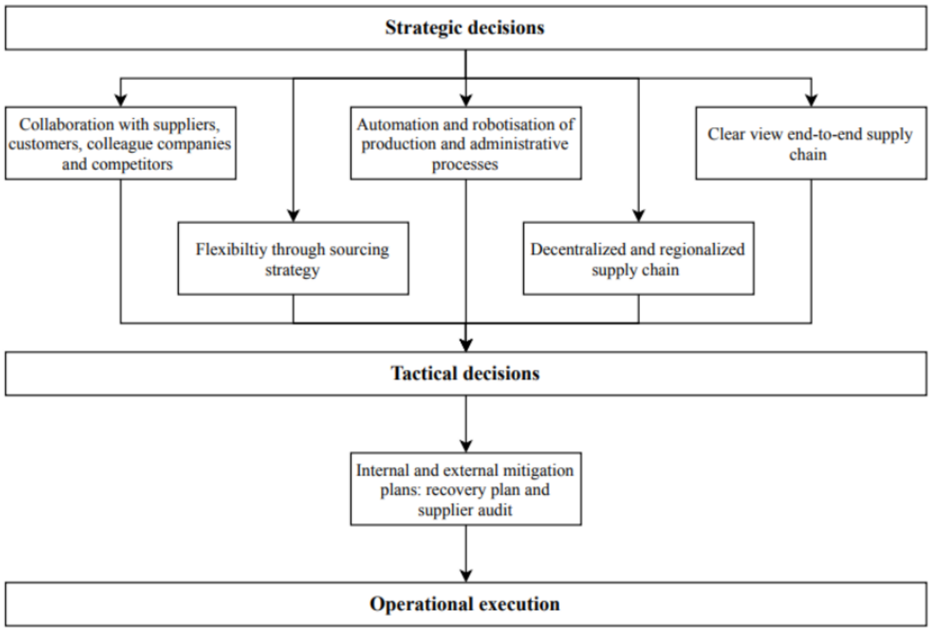


Figure 5 - Collaboration within Supply Chains

The Figure 5 above illustrates in what dimension collaboration should be discussed and implemented. Since collaboration with other chains in the supply chain is a strategic decision it has a clear impact on the way an organization should operate. By embedding the choice for collaboration in the strategy of the company, an organization can enable itself to better deal with disruptions. Therefore, supply chain resilience is a strategic choice when it comes to collaboration.

3.1.1 The Importance of Information Sharing

One of the key factors in collaboration for a better resilient supply chain is mainly focused on information sharing. Therefore, In the current day and age, organizations need a well-developed trust and information technology (IT) department. There is a clear need for information technology system to enable real-time data and information sharing between different links within the supply chain, such as about inventory levels and flow through rates with key suppliers. The development of information technology systems and trust go hand in hand, since this will only give the desired result if all organizations involved share the right information and trust each other.

Figure 6 - Trusted information sharing

Once organizations build trust within the supply chain, they are more willing to share information with each other. Information sharing is the extent to which an organization shares a variety of relevant information (relevant and complete plans, processes and procedures etc.) with other parties in the supply chain. Information sharing is an important enhancer of supply chain resilience. The aim of information sharing is to create a higher level of visibility both upstream and downstream the supply chain. This improves visibility, velocity and flexibility of supply chains. Visibility is the extent to which supply chain partners have access and or (timely) share information about their key operations to other supply chain partners. Velocity is the speed on which a supply chain can react to market changes.

To enhance the information sharing and collaborative communications, organizations need to consider the type of information that is shared, the frequency and the directions as well as the mode of information sharing. Quantity, direction and timing of complete, detailed and reliable data lead to more visibility and velocity in general, not only related to supply chain disruptions. Also, a lower level of information sharing and a lower level of collaborative communication reduce the flexibility, thus reduces supply chain resilience. Visibility and velocity are important drivers for supply chain resilience:

- Visibility is the extent to which different partners in the supply chain have access to, or timely share information about key supply chain operations. It is the ability to have a clear view on one end of the pipeline to the other.
- Velocity is the extent how an organization can timely response to market changes and it improves the recovery speed from supply chain disruptions. Velocity in supply chain resilience is concerned with two aspects. The first aspect is the total time required to transfer products and materials from one end of the supply chain to the other. Velocity involves the ability to have a clear view of all upstream and downstream information, such as inventories, demand and supply conditions and production and purchasing schedules.

Logically, velocity and visibility go hand in hand, so it is important that both are well organized to achieve supply chain resilience.

Of course, both concepts may have different details of understanding based on business models of the partners involved in the buyer-supplier cycle. Business models applied may contain various types of constraints: cultural openness towards partners, model of trust and safety, the types and details of guarantees on all sides, therefore data shared along processes may vary in both packaging, channels of distribution and frequency of update.

3.1.2 Direction and Focus

To ensure the best supply chain resilience according to the literature and the factors mentioned above, the following summary can be made: Supply chain resilience is most affected by the collaboration within the actual supply chain and the way organizations share information. Therefore, in order to design a resilient supply chain, it would be best to focus on the aforementioned dimensions:

3.1.2.1 Collaboration with competitors and/or colleague companies

- Companies need to build a certain level of **trust** in order to have a productive collaborative environment within a supply chain. Trust is essential to build a valuable and fair relationship with partners in the supply chain network. It however can take a lot of time to build trust and when it is violated it takes a long time to recover it. Therefore, all supply chain partners should have equal rights.
- In case of Additive Manufacturing companies need to used shared design standards regarding parts to be printed, geometric, material and functional dependencies between parts, also share the same approach to verification and validation of new designs.
- Companies need to work together with other links in the supply chain to **absorb the missing capacity** that is needed to counteract a supply chain disruption.
- Companies need to **synchronize decisions** to tackle any possible problems caused by internal or external disruptions.

3.1.2.2 Information & data sharing

- Companies need to facilitate based on their capability to connect, align in recognizable and accepted metadata format and publish data, to enable close to **real-time data & information sharing** within the chains in a supply chain.

- For **collaborative planning, forecast** and **replenishment** (CPFR) there is a clear necessity for **reliable and clean data**. CPFR is vital for supply chain resilience, as the information that is shared through CPFR has a direct impact on the resilience of a supply chain.

Companies need **guidelines,** shared metadata catalogues about which detail information that is shared, the frequency and the directions as well as the mode of information sharing.

3.2 Supply Chain Transparency Services

COVID-19 crisis asked for strategic thinking approaches where studied and exercised strategies have been challenged in terms of capability of adapt to unplanned strategies to collect relevant data in terms of impact, stress generated on medical facilities or patient management. Those issues asked for immediate workarounds in terms of matching between demand, logistics and production capacities.

Pre-pandemic perception of medical products exposed a profile with certain differences from regular consumer products. Those aspects impact subjects like the predictability of quality, availability of spare parts being usually served by a more specialized production units, pace of delivery close to a specific consumption rates. Radical changes ignited by pandemic exposed systemic threats that need to be covered with higher priority:

- Un-common or specialized designs and/or materials – due to the character of “special products” of medical spare part equipment, the availability of matching between design specification (mostly controlled by one or a very little number of producers) and the ones capable to deliver was difficult to occure. This aspect raised the need to make available or adapt systematic instruments like standardised information metadata to be exchanged and protocols for the whole communication process.
- Access of demand to industry grade brokerage services as Siemens Additive Manufacturing Network. Such brokerage services offer a certain degree of trust in the qualification of providers, domain knowledge and delivery capability. Should be noted that such services should be able to access validation of designs asked by demand against certified design and simulation tools before the order is facilitated toward potential 3D printing/manufacturing providers.
- Existence of a catalogue where critical pre-certified parts and assemblies formalised design and metadata are stored together in order to be available to un-specialized buyer for fast selection and use for orders generation towards brokers and trusted suppliers.
- Provision of connectivity for the catalogue to both trusted data spaces via trusted connector as a way to add and maintain parts and assemblies design, and to brokers via various mechanisms (e.g. a specific API) capable to fulfil the ordering process following a standardized mechanism.

During the first period of the project, Siemens worked to adapt his own Additive Manufacturing Network platform to support the needs listed before. Siemens Additive Manufacturing Network provides a set of services usable to meaningful connect various demands ranging from mass production of designs up to niche spare parts. Its role is to connect demand with the right suppliers, knowledge, expertise and technology partners needed for complex industrial scenarios, all those in a safe and trusted ecosystem where enablement of instant generalized collaboration proves to be a must.

In order to validate identified functional demands identified along with information transparency and trust along supply chains, Siemens AMN developed as a side component of the main platform a catalogue component accessible to various personas identified in the potential process. Below are observable the roles identified acting in a crisis context. All those roles are related to the generation, identification and ordering of certified parts via Siemens AMN catalog. Of course, each role is generic for identified crisis context and it serves only to demonstrate key features implemented.

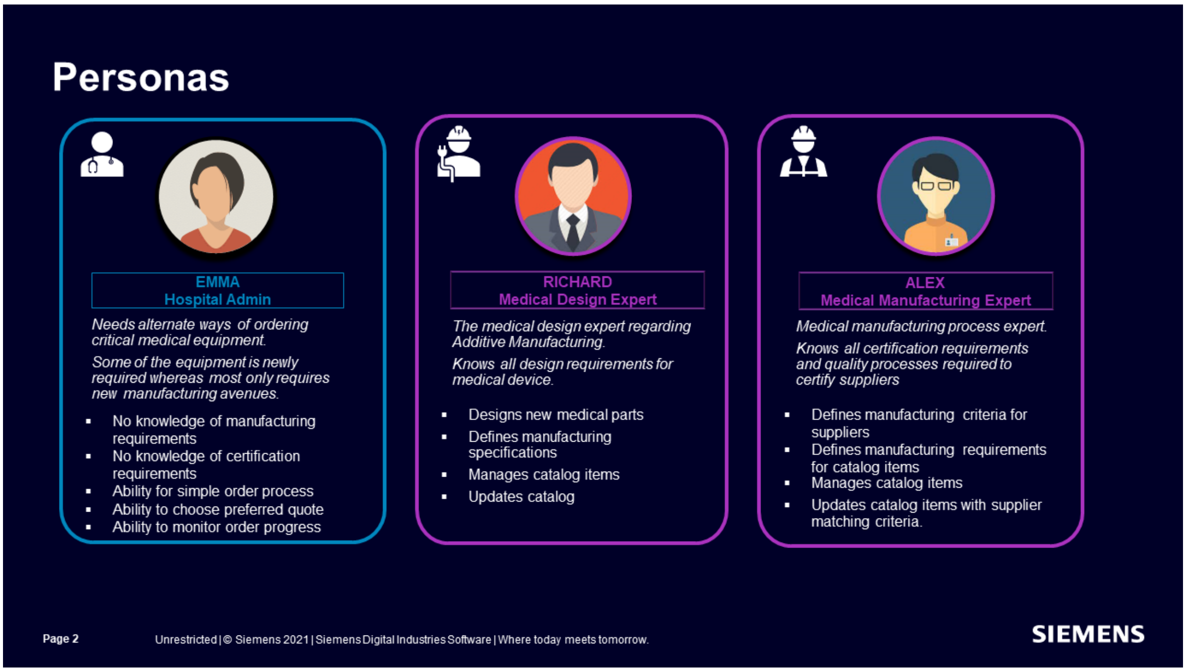


Figure 7 – AMN Actors

As for current moment various functional aspects are under various levels of implementation and functional maturity. As a vision, the following picture reflects the informational and functional flows that we aim to demonstrate.

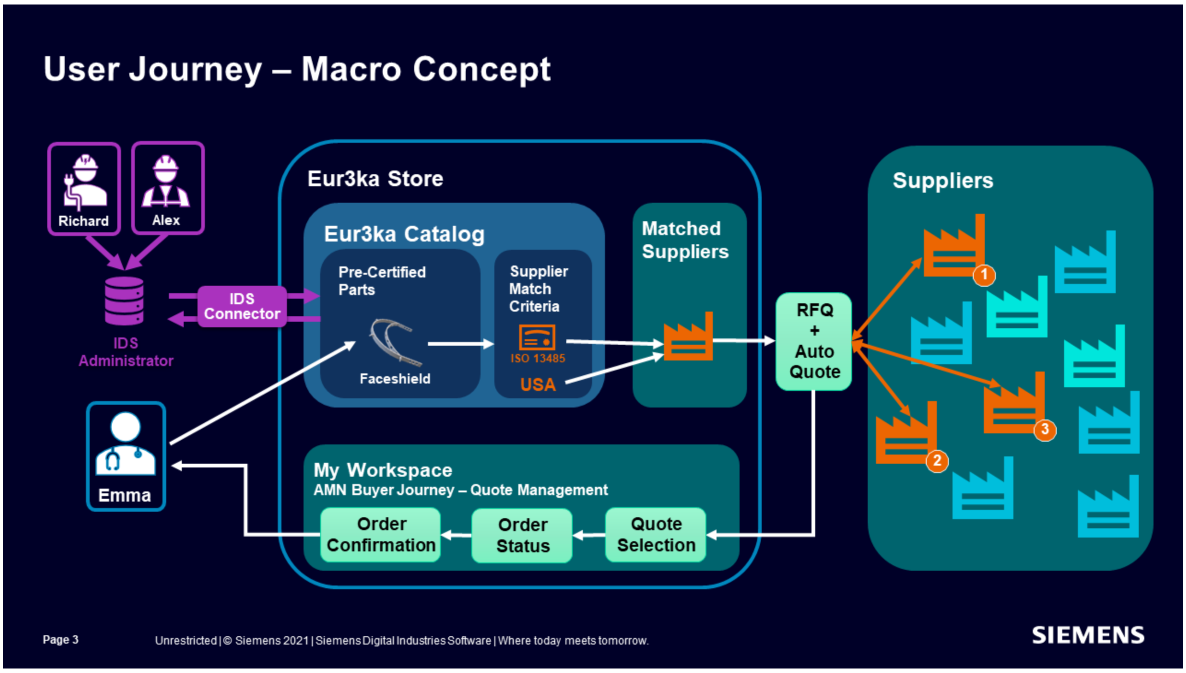


Figure 8 - AMN User Journey

When you do not have time to generate and obtain mutual trust, either because you are just entering a new market, or because you are tasked with delivering a new product in a crisis, you can validate the supplier products yourself or you can look for external validation of suppliers and products. As an example, in the COVID19 initial phase, PPE (Personal Protection Equipment) demand was much larger than the supply from trusted suppliers and several cases of underperforming products were discovered. In the case of PPE's, validating supplier quality was suddenly needed and as an example, Danish Technological Institute as a third-party tested <15 masks in the duration of 2020 for qualifying suppliers. In this way, underperforming masks and even falsified test certificates were discovered.

In a normal situation, certification and validation of industrial products is a common part of manufacturing and especially for extremely critical components, external bodies exist for validating manufacturing lines as well as products. For medical devices especially, the concept of notified bodies, government approved third parties, must accept all steps of manufacturing e.g., vaccine manufacturing sites or components with the risk of explosion. These approvals demonstrate how manufacturing sites follow, for instance, strict quality management systems, e.g., ISO 13485 for medical device manufacturing.

However, when neither the time to build trust nor the cost to obtain third party approval is present, how can you gain insight into the quality of your products? In Denmark, a sudden demand in visors for the health care system led to private makers providing support in manufacturing the holder part using hobby 3D printers, organized using the Facebook page Makers against corona. Thousands of visor holders were manufactured, and used, generally without payment, but just for providing much-needed assistance. However, some of these were rejected due to poor quality and lack of trust.

But how could trust have been gained in this context? If the people in need were experts in 3D printing, they could easily provide quality demands to the products they would receive, but in general all the knowledge was centered at the makers. Additionally, knowledge on the validation needs was lacking at both the maker and health care side, leading to a mismatch in trust. The third leg, validation and certification, was lacking.

This is investigated in this project and a catalogue for trusted parts (as previously described) has been developed and will be tested in the context of makers. The idea is to utilize knowledge from industrial quality management and medical device regulation and apply this to the maker world using simple tools and guidelines as well as utilizing production data to validate productions. Here some parts will be pre-validated, I.e., product specifications, manufacturing specifications and validation and quality assurance methods will be demonstrated by a third-party expert (here Danish Technological Institute) and the medical professional can safely order components from makers using the platform catalogue. This will create transparency within the relationship between supplier and customer and can be applied to other cases as well.

3.3 Resilient Supply Chain Design Tools

The Resilient Supply Chain Design Tool focuses on enabling better **trusted collaboration** in the supply chain by more **real-time data sharing** for **collaborative planning, forecasting,** and **replenishment** as has been introduced earlier in this chapter. The basis of this tool is the Smart Connected Supplier Network (SCSN).

Current situation: Smart Connected Supplier Network

Smart Connected Supplier Network or SCSN is an open communication standard for exchanging order-related data between various types of (industrial) organizations (i.e. within the supply chain). The standard focuses mainly on low-volume, high-mix, high-complexity sectors where many organizations work together to manufacture products. In order to offer as much interoperability as possible between multiple organizations, the SCSN initiative intends to support many of the existing industry-standards.

In order to provide a communication network wherein (high-tech) manufacturers are able to easily exchange order information, SCSN is constructed out of two main components:

1. **SCSN message standard**

Based on other industrial standards such as the Universal Business Language 2.1 (UBL) by OASIS and the CEF Digital Building Block invoicing, the SCSN message standard helps manufacturers to determine and agree on which format is standardized for certain types of information. The SCSN has a wide variety of message types, ranging from Bill of Materials and Production specification to Invoice and Price catalogues. Overall, SCSN provides message specifications for every purchase-to-pay scenario. A full overview of all message types with additional information is accessible through the SCSN Semantic Treehouse.

2. **SCSN technical infrastructure**

By making use of the four-corner model, the SCSN network consists of multiple networks. Each service-provider and each broker are directly connected which allows any manufacturer within the SCSN to connect and exchange information with other manufacturers in the network, independent of the service provider any manufacturer is connected to.

This network-model is easily comparable with our consumer telecommunications. Anyone is free to choose a service provider that provides the best offer, but by allowing service providers to connect with other service providers, the end-user is able to connect to anyone connected to a service provider in the network.

In the case of SCSN, the technical constraints and commercial agreements between service providers are managed by the independent SCSN Foundation.

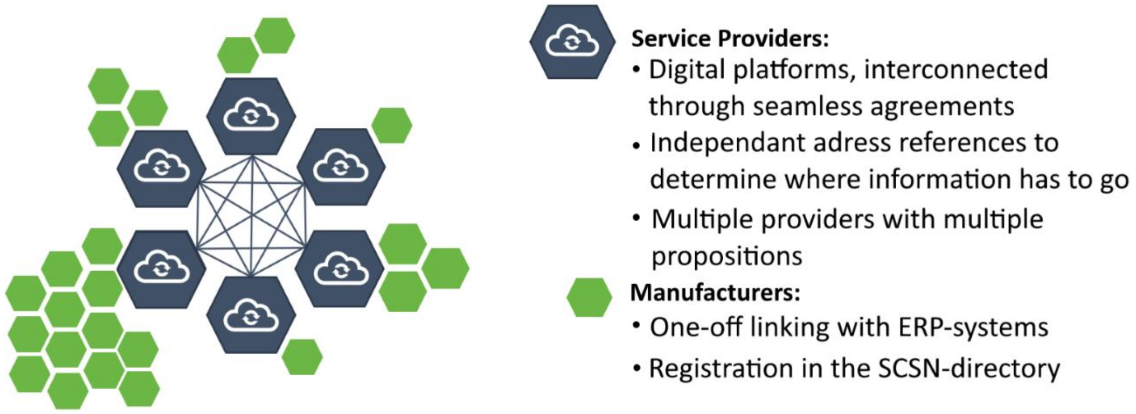


Figure 9 - Technical constraints and commercial agreements

Next steps: Resilient Supply Chain Design Tool

With the above factors in mind, an additional system is designed on top of existing data sharing and semantic technologies to rapidly identify possible replacements for broken links in the supply chain to increase the resilience of the supply chain. Consider an ordering organization in the supply chain as a node in SCSN. In the scenario where a highly specialized product is no longer available to be made from an existing supplier, a resiliency flow can be defined as follows to rapidly identify other supplier organizations which can pick up the slack. This process is supported by the Resilient Supply Chain Design Tool.

A sample ontology of capabilities is presented below, which can be expanded upon by industry experts. Because the focus of the manufacturers is on highly specialized products, the way of identifying potential suppliers is to search based on manufacturing capabilities.

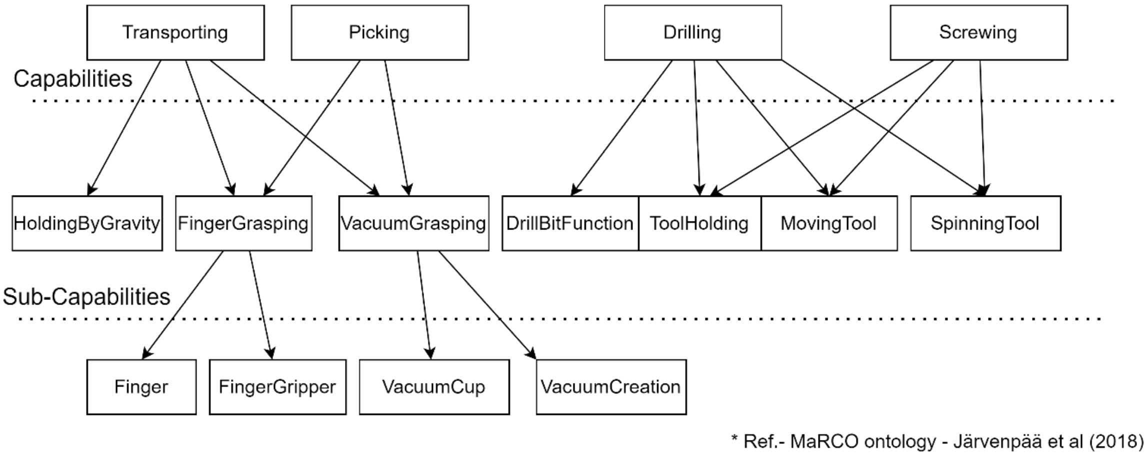


Figure 10 - Ontology of capabilities

The ordering organization can accordingly define a set of capabilities with parameters that are required to design its highly specialized product. Every organization might contain some capabilities of their own, but critically is able to refer to the Broker in the dataspace to find other organizations that could possess the capabilities it lacks. This is represented in the figures below.

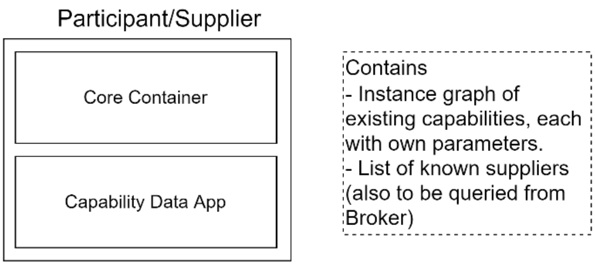


Figure 11 - Capabilities referred to Broker in DS

In a sample flow for this resiliency approach, the ordering organization first queries the Broker within its own dataspace to identify other suppliers that participate in the resiliency sub-network. A query is sent to each supplier with the list of requirements, and each supplier can first verify if they themselves contain the capabilities (with the required parameters), and if not, they recursively query sub-suppliers that might instead have capabilities or sub-capabilities (which could be combined) to suit the incoming list of requirements. The key part is that the ordering organization remains unaware of the recursive queries and receives only the final answer/quote from the main suppliers.

This enables manufacturing companies to source new suppliers in a standardized way by and to setup new **collaborations** within a **trusted network** they are already using for exchanging purchase-to-pay information. The standardized sharing of manufacturing capabilities can help companies to handle large deviations in demand by sourcing from new suppliers when necessary, therefore increasing their **resiliency**.

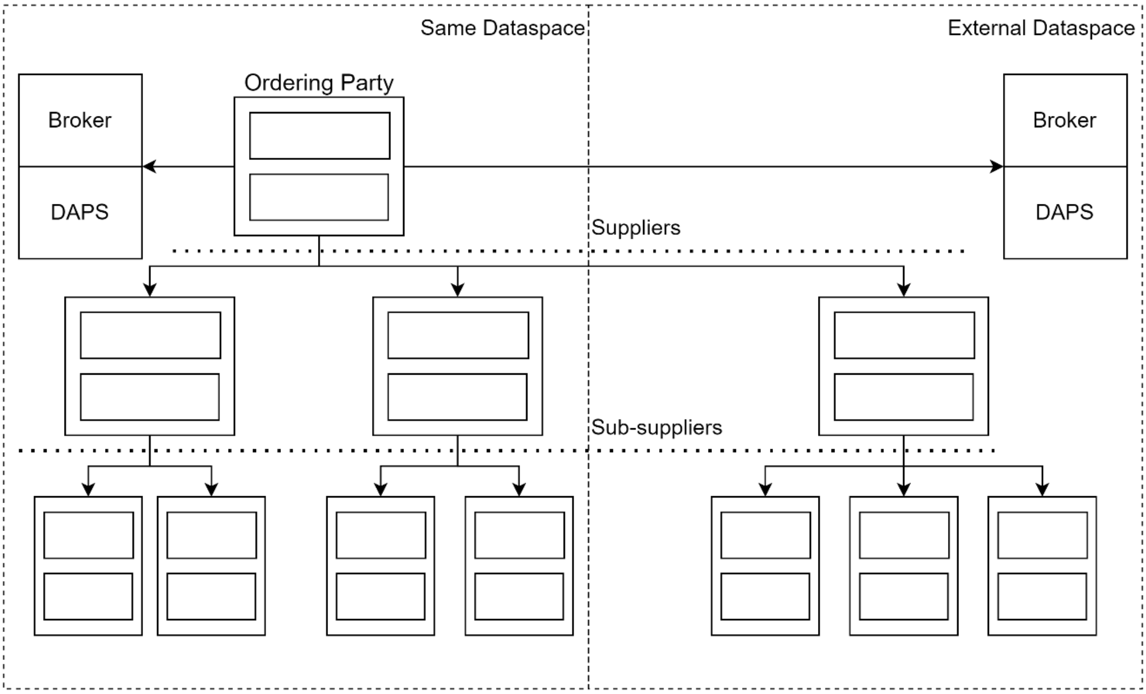


Figure 12 - Collaborations within a trusted network

From a technical perspective, this flow is built upon the International Data Spaces (IDS) infrastructure in combination with semantic technology in compliance with the Eur3ka infrastructure.

For future scope, the following actions are defined.

- The ontology for manufacturing capabilities used for the example is one of many that are currently being developed in academia, and the designed flow is meant to be agnostic and configurable with respect to switching to other options. With some industry adoption and standardization, the system would become easier to scale. Moreover, further alignment with the SmartFactoryWeb (4.1) is required.
- With the development of a feature known as the Federated Catalogue (logical combination of a Self-Description repository and search algorithms so that Self-Description-based attribute searches can be processed. The Catalogue is related to the facilities/factories with the manufacturing assets to produce the products in the Eur3ka Catalogue. The catalogue of Eur3ka facilities is populated on the basis of the certification/qualification processes that the eur3ka network and partners provide), it should be easily possible to expand a search radius to external dataspaces. For instance, an ordering organization in Europe might be able to query external compatible dataspaces in Japan or Asia if no satisfactory suppliers are possible in its own dataspace.
- Piloting of the solution in an industrial setting to validate the solution.

4 Robust On-demand Manufacturing Networks

4.1 Smart Mediation & Matching Services

The Smart Matching and Mediation Application (SMMA) is a web service with an HTTP REST interface. It filters and sorts a given list of supply chains based on the constraints specified in the request. For this purpose, it fetches sensitive data directly from factories and handles the data in a trusted manner. The modular design allows easy integration of new constraints and sorting algorithms as well as different sorting strategies.

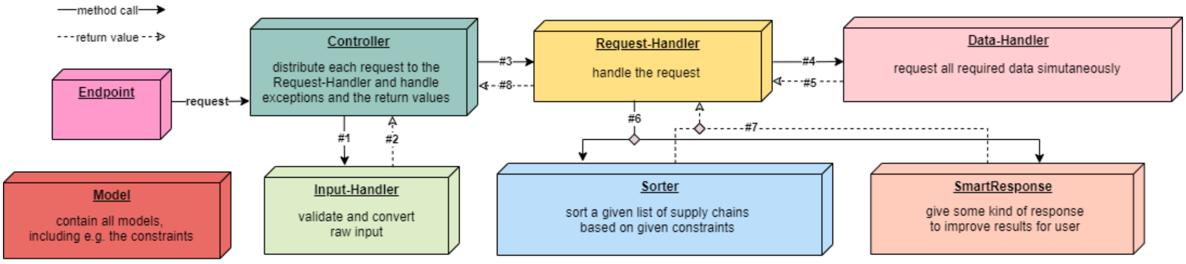


Figure 13 - SMMA component overview

Figure 13 gives an overview of the components of the SMMA Architecture. In the following, all the modules of the SMMA are described:

- **Endpoint:** Through the HTTP REST endpoint a request can be posted to the SMMA.
- **Controller:** The Controller receives the request from the endpoint and is responsible for organizing the calculation of the response. It dispatches the resulting tasks on the first level.
- **Input-Handler:** The Input-Handler is used to check the raw input for a valid structure and proper assignment of all needed data. If there are no errors, the input is parsed into an internal model object.
- **Request-Handler:** This module implements all possible requests of the SMMA and performs the actual “work” part of the request. It dispatches the parts of the request to the related components and combines the results afterwards.
- **Data-Handler:** The Data-Handler encapsulates functionality to fetch data from different factories. It is equipped with an in-memory cache so that data that has been fetched recently can be accessed without a new request to the associated factory. By fetching data asynchronously, the maximum waiting time for all requests is limited to the predefined timeout time of a request.
- **Sorter:** The Sorter module consists of a modular and interchangeable rating algorithm, which rates all given supply chains based on the fetched constraints. These rated supply chains then get sorted with their assigned weight. Sorting the supply chains by rating them and not sorting them directly makes it possible to rate each individual supply chain without having any information about the others. This enables asynchronous calculation of the sorting index of the supply chain.

- **SmartResponse:** The SmartResponse module is used to calculate a response for a user containing information such as optimized constraints to improve the results.

To illustrate the function of the SMMA, we briefly describe the dataflow of a request. When a request arrives at the endpoint, it is forwarded to the controller. The Controller forwards the request to the Input-Handler, which checks the given raw input for proper structure (#1). The response from the Input-Handler is either an error, if the input format is wrong, or an internal model object (#2). The given model object from the Input-Handler is passed onto the Request-Handler (#3). In the next step, all required sensitive data is requested from the Data-Handler (#4/5). Next, the Sorting Module starts rating and sorting the supply chains. Additionally, the SmartResponse module calculates different constraint variations to show opportunities for enhancement of the result (#6/7). In #8, the Request-Handler responds to the Controller with sorted supply chains based on the given constraints.

SMMA is not yet available as a public repository yet, but it is planned to open source the SMMA in early 2022.

Below we describe the used data structure of a request to the SMMA and the data structure of the calculated result of the SMMA.

4.1.1 Data structure

This section describes the data structure of a request to the SMMA.

Request

```
{
  "Constraints": [
    {
      "Order": "asc",
      "Min": "",
      "Max": "",
      "Value": "5",
      "Id": "Price"
    }
  ],
  "SupplyChains": [
    {
      "Factories": [
        {
          "FactoryConnectorUrl": "https://provider-a-connector.com/api/offers/...",
          "FactoryId":2489512,
        },
        {
          "FactoryConnectorUrl": "https://provider-b-connector.com/api/offers/...",
          "FactoryId":1324845,
        },
        [...] <!-- possibly more factories -->
      ],
      "NumberOfFactories": 2
    },
    [...] <!-- possibly more supply chains -->
  ]
}
```

The HTTP body of the SFW request is in JSON format. It contains a list of supply chains, and another list of constraints. These constraints are relevant for the SMMA calculations. A constraint could be, for example, the sort order or the maximum price of a whole supply chain. The other important field for the SMMA is the “FactoryConnectorUrl” inside the factories of a supply chain. This URL points to the sensitive resource data that is used to perform calculations. Apart from this, each factory contains a number of SFW specific fields that are not relevant for the SMMA.

4.1.2 Response

The SMMA’s response, also in JSON format, contains the same list or filtered list of supply chains as in the request, sorted according to the given constraints.

```
{
  "Id": 0,
  <!-- some metadata like number_of_supply_chains etc. -->
  "Constraints": [...], <!-- same as in request -->
  "SupplyChains": [
    {
      "Factories": [
        {
          "FactoryConnectorUrl": "https://provider-a-connector.com/api/offers/...",
          "FactoryConnectorReachable": true,
          "FactoryId":2489512,
        },
        {
          "FactoryConnectorUrl": "https://provider-b-connector.com/api/offers/...",
          "FactoryConnectorReachable": true,
          "FactoryId":1324845,
        },
      ],
      "number_of_factories": 2,
      "id": "738069221",
      "sorting_index": 1,
      "all_factories_reachable": true,
      "constraintsFulfilled": false
    }
  ]
}
```

Furthermore, the following properties are added to the response:

- To identify the reachability of a factory, the field “FactoryConnectorReachable”, and for the reachability of a whole supply chain the field “all_factories_reachable” are added.
- To identify a supply chain that fulfils the given constraints, the field “constraintsFulfilled” is added.
- The field “sorting_index” is added, so the parsing of the response is made easier.

Additionally, general statistics concerning fulfilment and reachability are presented at the beginning of the JSON response.

4.2 Production Quality Control Digital Workplace

To ensure dimensional quality in production particularly with respect to 3D printed parts is of utmost necessity in an on-demand manufacturing network that processing and analysis of current manufactured parts can be performed effectively. This implies both the collaborative measurement of the information captured with high accuracy usually in the form of a point cloud or to perform the full lifecycle of metrology 4.0 delivering the manufactured part for control to the metrology laboratories from the factory and/or production site that has manufactured the part under test.

For such a digital workplace, Eur3ka is implementing advanced functionalities (MiWorkspace) in the M3Workspace platform. While traditional platforms allowed one to many (broadcast) type communications to deal with more general collaborative functions, Eur3ka has implemented the functionalities that demand a Peer 2 Peer (P2P) approach in such collaboration and that are fundamental to delivery of a more customised QC digital service. In order to implement such individual data spaces, Eur3ka is developing a QIF (Quality Information Framework) ISO23952 compliant environment to drive the dimensional quality control operation that should support v3.0 of the standard and ensure seamless data exchange and sharing between reference quality control software platform and the Eur3ka digital workplace.

The rest of the Section will describe the features that are enabled via MiWorkspace and the data model used to support Eur3ka data space operation and platform federation.

Eur3ka smart data model for measurement and dimensional supply chains 4.0

The Eur3ka digital workspace allows the analysis of files and information that respect the Boost 4.0 and Qu4lity data models for metrology 4.0 and therefore adopt QIF/ISO 23952, STEP/ISO 10303, CAD and plain txt (point cloud) files. These formats are critical to ensure full traceability and implementation of a model-based approach to metrology 4.0. Eur3ka is adapting legacy data models to v3.0 of the standard so the manufacturing network can exploit increased traceability and interoperability capabilities in the standard.

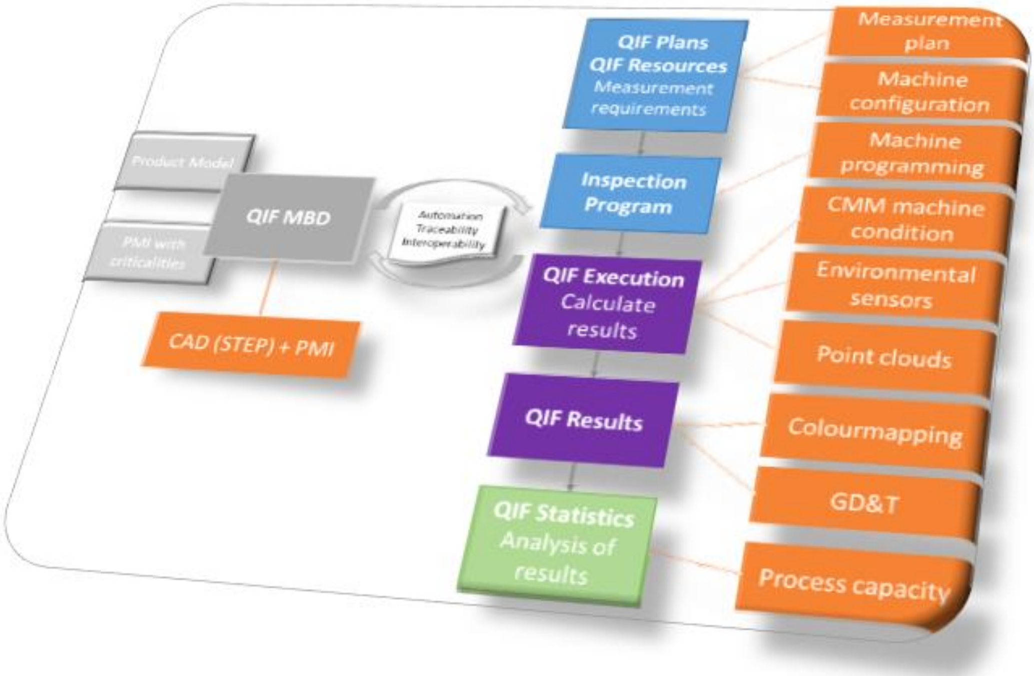


Figure 14 - Metrology 4.0 approach

The metrology 4.0 semantic approach adopted by the Eur3ka digital workspace allows a featured-based implementation of the dimensional control of the manufactured part in a distributed environment. The workspace relies on the trusted and sovereign exchange of such information exploiting [IDSA RAM model] for data space.

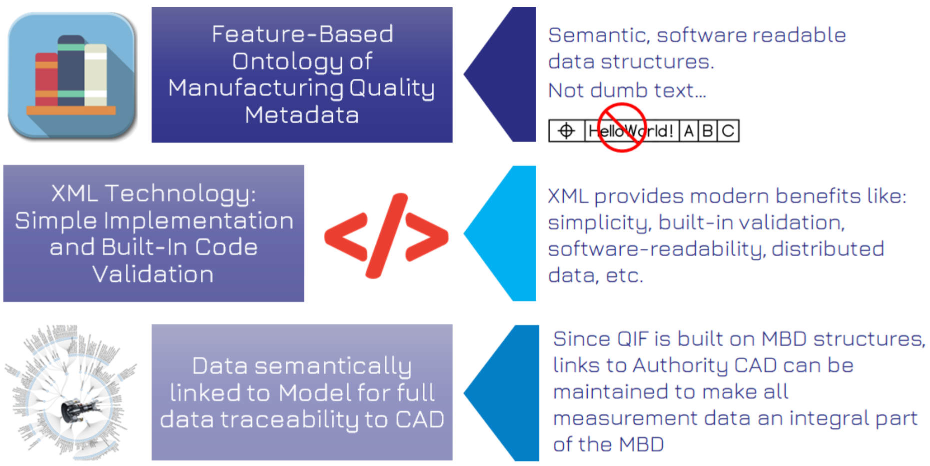


Figure 15 - MiWorkspace semantic support

Eur3ka Model-based metrology 4.0 collaborative engineering for Manufacturing as a Service (MaaS)

MiWorkspace semantic support allows the realisation of the green functions shown in the picture below mainly related to QIF results and statistics functions with enable automation, optimisation, analysis and traceability of results across the peers involved in the 3D dimensional quality control function.

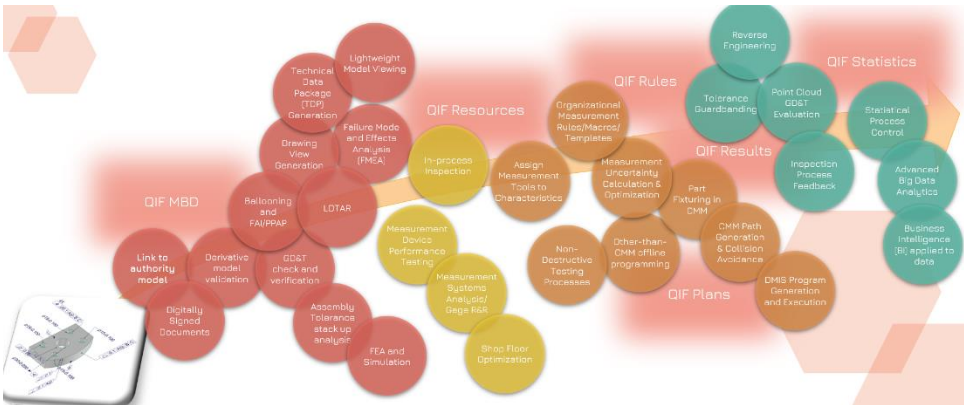


Figure 16 - Metrology 4.0 model-based approach

The metrology 4.0 model-based approach allows that CAD geometry is wrapped by features. This is a different concept from CAD features, sometimes referred to as tolerance features, metrology features or measurement features. Features are referenced by Characteristics, which usually, these are Geometrical Dimensions & Tolerances (GD&T).

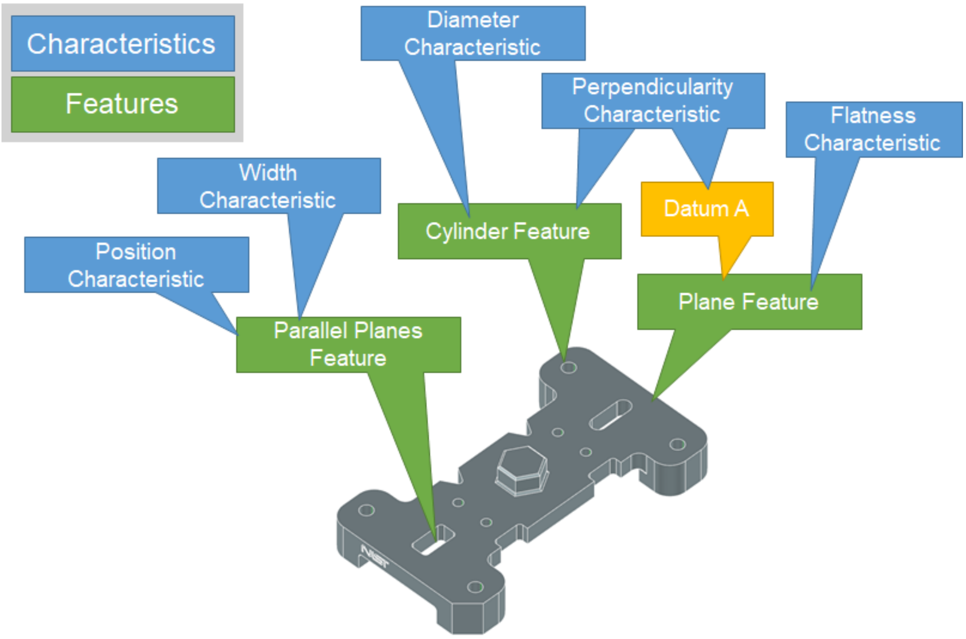


Figure 17 - MiWorkspace functionalities

The development of MiWorkspace functionalities allows the development of measurement and dimensional control supply chains implemented over distributed manufacturing networks as a service.

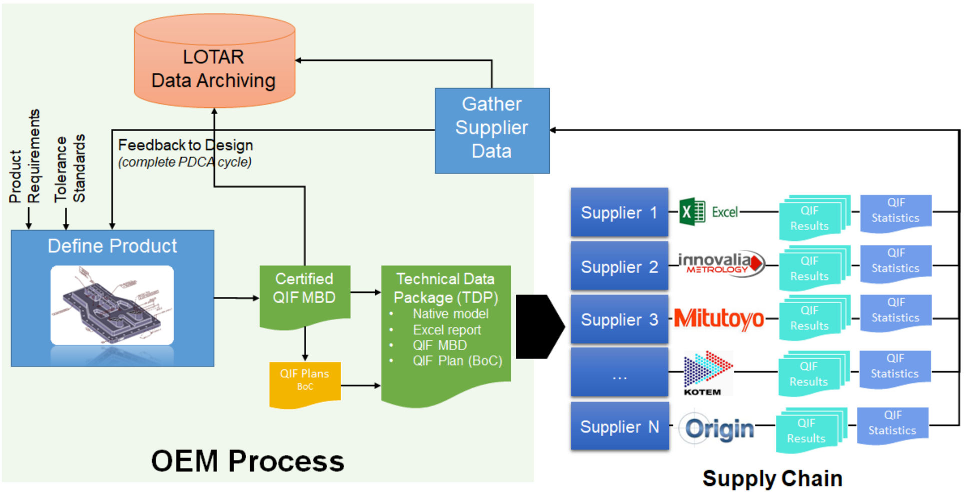


Figure 18 – OEM Process

Eur3ka Model-based metrology 4.0 service supply chain platform

The Figure below shows the functions that allow the implementation of such metrology 4.0 service supply chains over collaborative and standardised data spaces.

Figure 19 - Implementation of metrology 4.0 (1)

Figure 20 - Implementation of metrology 4.0 (2)

Thus, Eur3ka Digital Workplace could deal in a collaborative environment with a number of formats, visualisation and analysis files that would ease the quality control functions by non-experts or the support of the quality control functions from a team of experts. The following reference part has been used in the process, which shows how the part can be digitised by means of point cloud representation, then transformed into STL files for visualisation and analysis/reverse engineering for 3D Printing purposes.

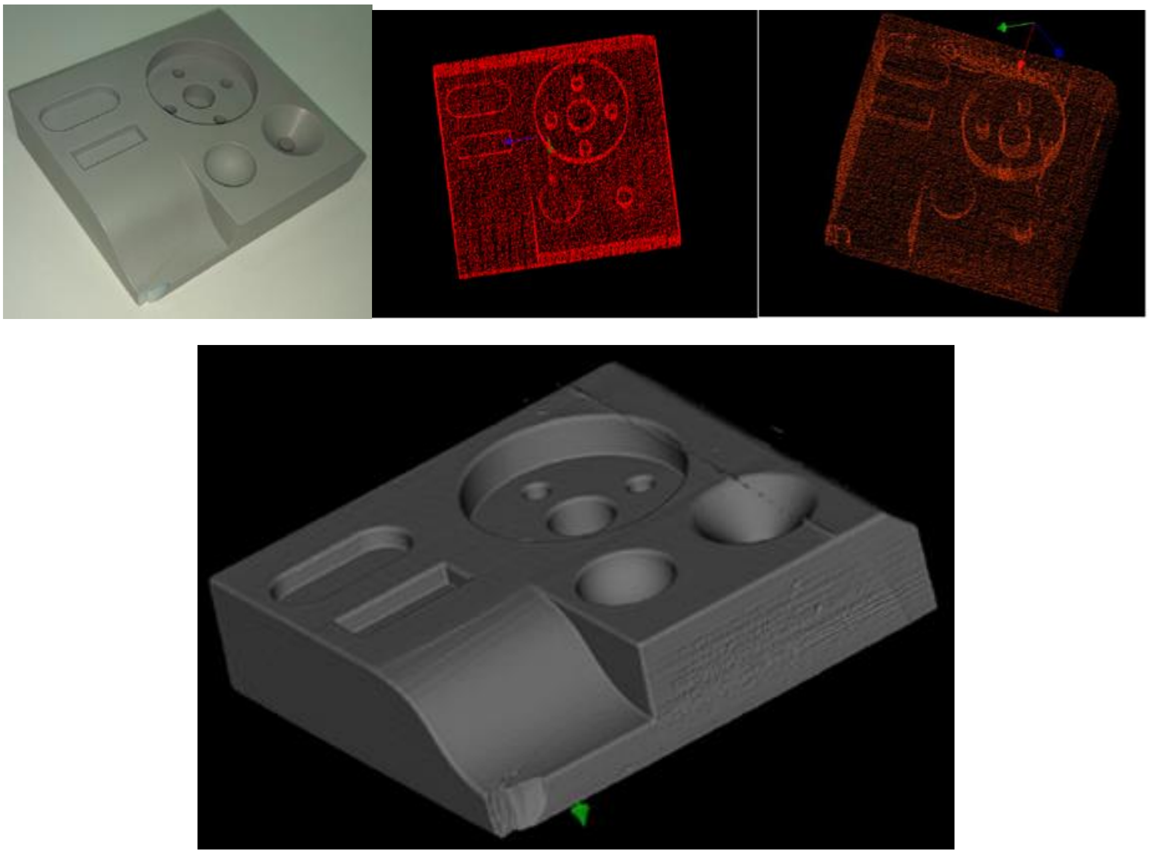


Figure 21 - 3D Printing example

Over these structures the digital workplace allows the implementation and collaborative design of both the inspection/measurement plan to process and analyse the point cloud information.


```
<QIFDocument ...>
<QPId>AFD08F25-CAE6-4647-9667-
674D5D66033F</QPId>  ...
<Product>   product contents   </Product>
<Plan>   plan contents   </Plan>
</QIFDocument>
```


Once the measurement process is completed it is possible to share information across multiple stakeholders in a standardised manner for further use and certification.


```
<QIFDocument ...>
<QPId>AFD08F25-CAE6-4647-9667-674D5D66071A</QPId>  ...
<Product>   product contents (same as in previous snippet)
</Product>
<Plan>   plan contents (same as in previous snippet)   </Plan>
<Results>   results data here   </Results>
 </QIFDocument>
```

Thus, the Eur3ka digital workplace supported by the M3Workspace functions allows a multi-stakeholder collaboration environment on the basis of a trusted and sovereign data exchange infrastructure and service.

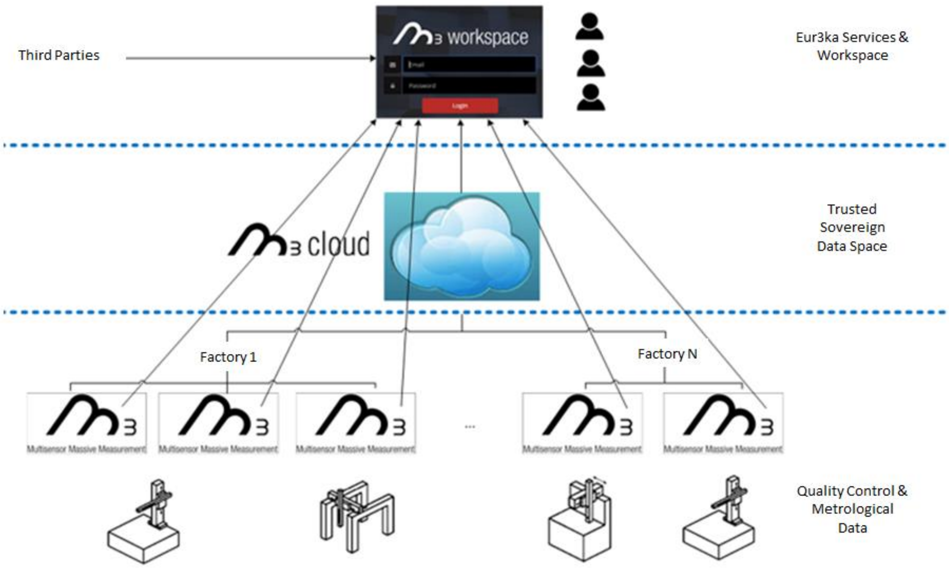


Figure 22 - Multi-stakeholder environment

The foundation of the entire process lays on three standards that determine how data is received, transformed and used with the required level of quality. These standards are:

- STEP AP242: An exchange format that allows Model Based Definition where Product Manufacturing Information is directly associated with the 3D CAD model.
- GD&T system: A Geometric, Dimensioning and Tolerancing system for defining and communicating engineering tolerances and relationships. It uses a symbolic language on engineering drawings and computer-generated three-dimensional solid models that explicitly describe nominal geometry and its allowable variation.
- ISO 23952:2020 - Quality information framework (QIF): This standard defines an integrated set of information models which enable the effective exchange of metrology data throughout the entire manufacturing quality measurement process – from product design to inspection planning to execution to analysis and reporting. This includes a framework for data format.

M3 Workspace enables the storing of a part design specification represented in a CAD model created under the STEP AP242 standard and the merging of this information with the part's geometrical, dimensional and tolerance characteristics by using the GD&T standard, as well as the management of the entire quality control process (equipment and operation, type of information to gather, data format and the results from the measurement process) via ISO 23952:2020. Thus, M3 Workspace is able to manage – in an integrated approach – this entire process and information. Therefore, a typical workflow would begin with the integration of a CAD model developed under STEP AP242 standard and then a measurement program and control of results are implemented by following the ISO23952:2020 standard. If a different data format framework is used, such as those implemented by other equipment manufacturers, M3 Workspace enables data model migration to ISO23952:2020 standard as this feature is integrated in this solution. In summary: the common standard is ISO23952:2020; the geometric, dimensional and tolerance data is handled via GD&T standard, the part specification is done by the STEP AP242 standard and the entire process is managed by M3 Workspace.

5 Rapid Reconfiguration & Production Line Continuity

5.1 Business Continuity Framework

To maintain business continuity during the COVID19 pandemic a smart shift allocation between staff workers can be applied to prevent infection spreading. The shift allocation is delivered as an autonomous software solution that includes a web UI for interactions with operators. The operators by using the web UI can define the production plant departments and assign employees and define their skills. The department can be further divided into sectors to ensure appropriate distancing between employees during a shift. Each department employees will be automatically assigned into sectors and shifts per sector according to their skills. Currently the tools support's 4 types of shifts: morning, afternoon, night and emergency shift. During the emergency shift there are available employees that can be selected in case of contagious events to replace colleagues that might have been infected.

5.1.1 Employee Management

The smart shift allocation system supports a personnel management user interface . The supported operations include:

- Employee insertion: A new employee is inserted into the system by defining name, skills and the department to be assigned. Also his availability to be assigned into shifts immediately is define as working status. Employee update: An existing

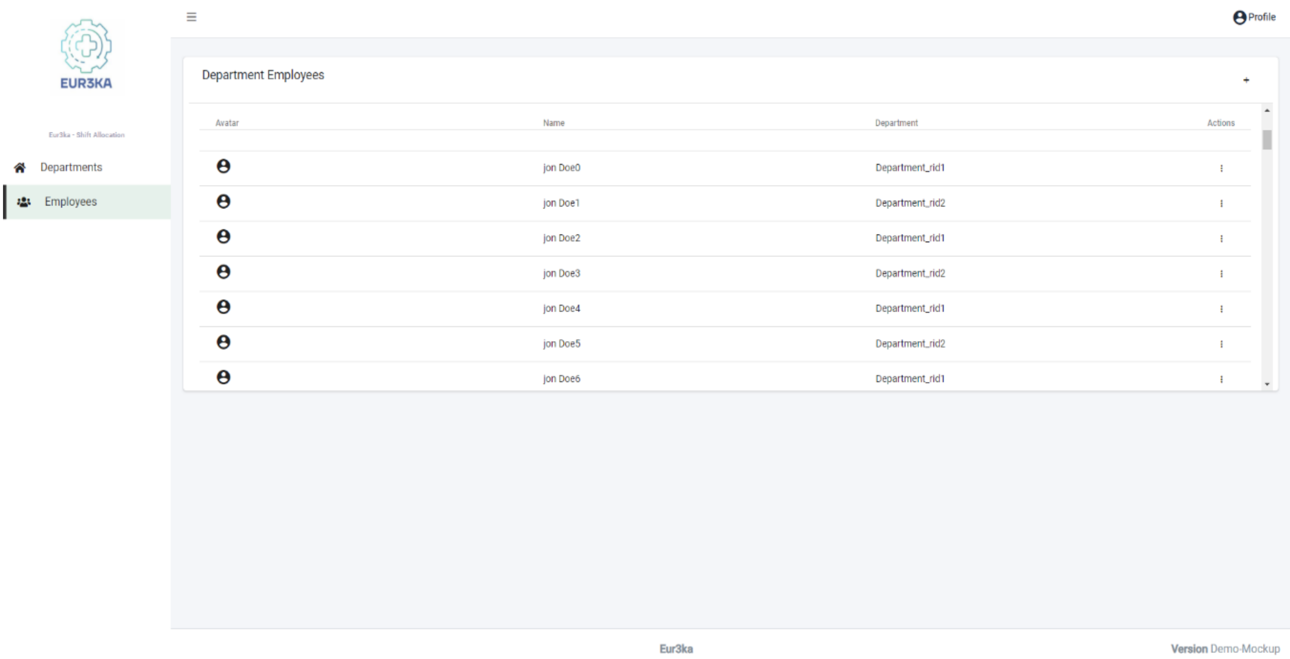


Figure 23 - Employees overview

employee can be updated by correcting name, defining new skills, or changing the assigned department.

In the figures below the corresponding dialogues for inserting a new employee, updating his skills and department assignment are presented in forms of popups dialogues. The skills are a collection of strings that are inserted into the system according to the organization requirements.

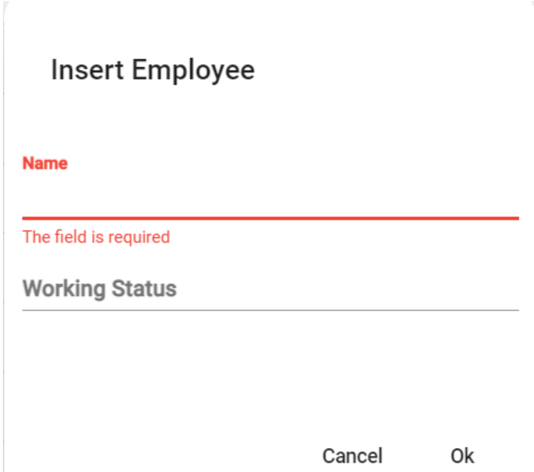


Figure 25 - Inserting a new employee

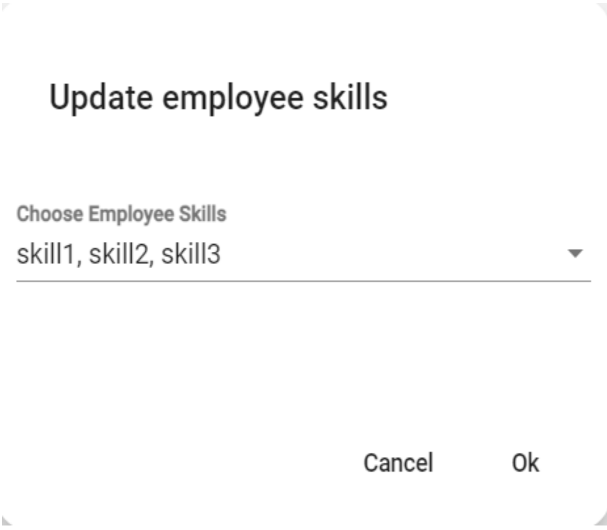


Figure 26 - Updating employee skills

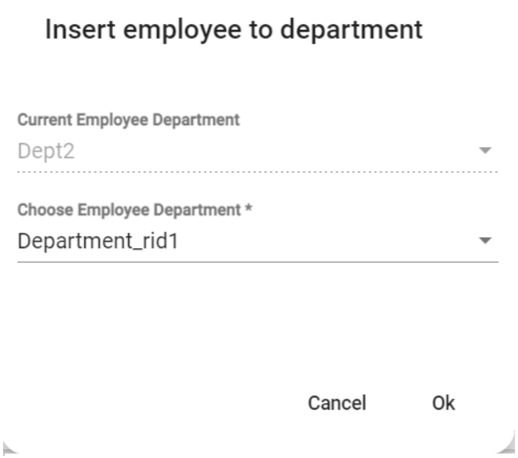


Figure 24 - Inserting employee to department

5.1.2 Department Management

After inserting employees, the operator can inspect them in a vertical scroll-view as seen in Figure 27, in this scroll-view each department is visualized as a card having as information the department name, the number of assigned employees and the sectors that the department has been divided into. By pressing the **Add Department** button a new department can be inserted into the production plant by defining its name and the location if available.

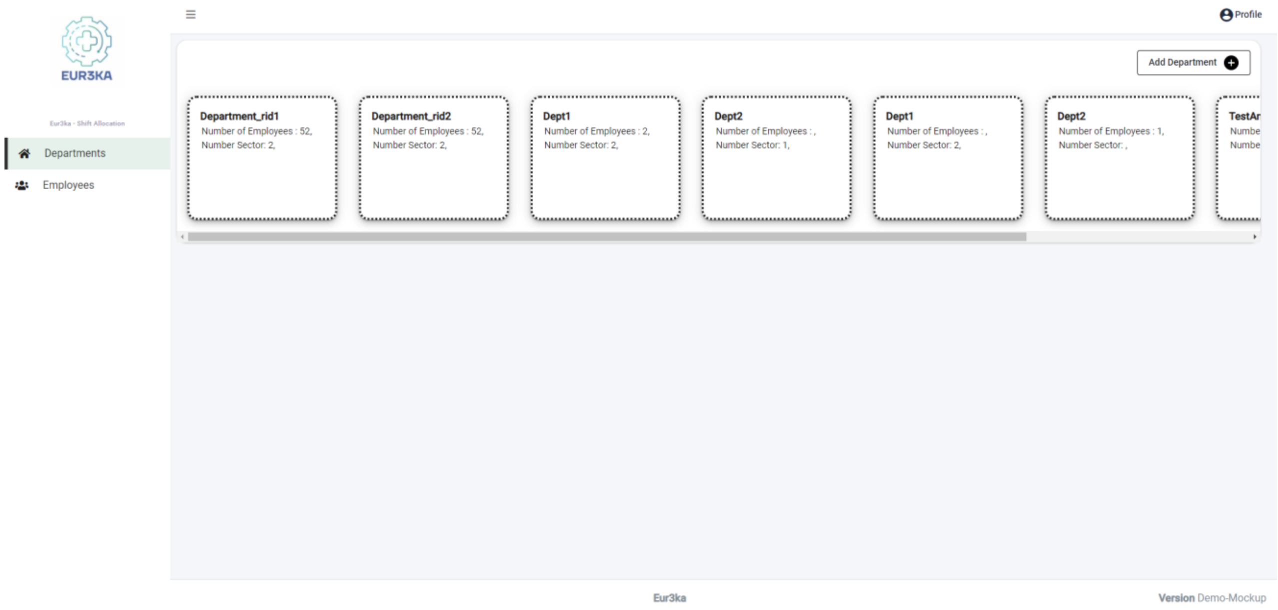


Figure 27 - Departments overview

By clicking upon a department then a redirection into a department page is performed. The department page includes department related information that include the number of assigned employees, the number of sectors and the number of COVID19 incidents that have been reported in the specific department. Also, the individual lists of sectors and employees in the selected department is visualized. The operator can perform the following:

- Sector insertion: A new sector can be inserted to divide the department by defining its name and the maximum number of employees that can be assigned into the new sector shifts so that the COVID19precautions can be complied.
- Sector update: An already inserted sector can be updated, and the operator can define the set of skills that employees need to follow in order to be assigned into the corresponding shifts.
- Report insertion: The operator can report possible COVID19 infections of the department personnel.

Shift Management: The operator can select to automatically assign department employees to shifts by selecting the commands from a dropdown menu. The command can be either to initialize the shifts or use the existing shifts which will be shifted automatically among employees and will be available from next week.

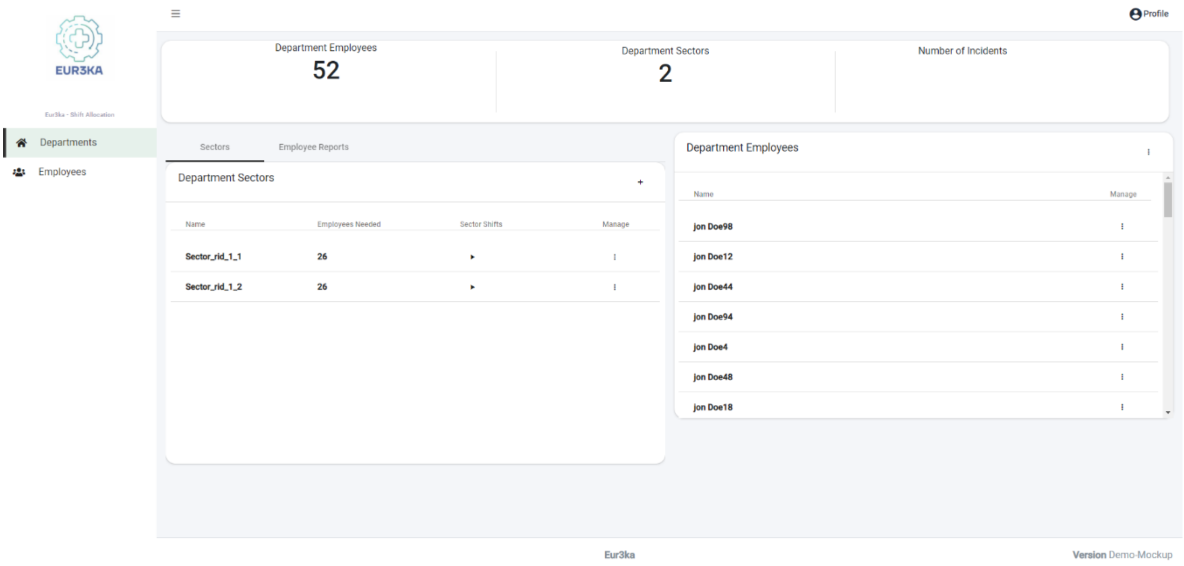


Figure 28 – Selected department overview

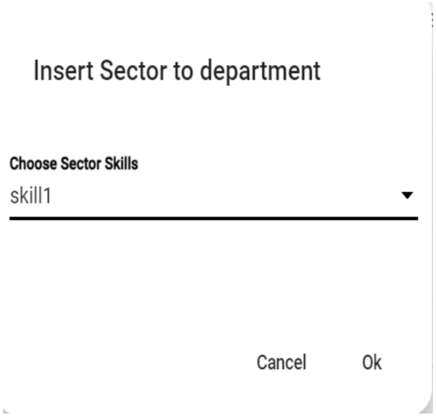


Figure 31 - Inserting skills that employees need to follow for the specific sector

Figure 29 - Inserting new sector to department

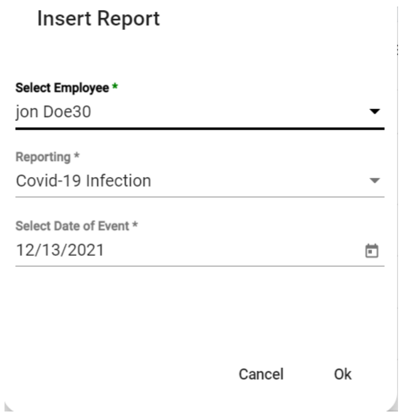


Figure 30 - Inserting COVID19 related reports

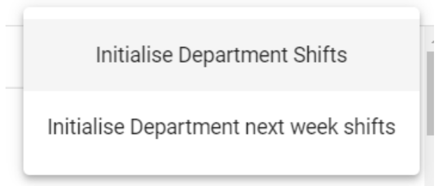


Figure 32 - Initializing shift allocation algorithm

5.1.3 Shifts Overview

By selecting a sector from a department, the operator can review the shifts automatically assigned by the tool in a form of an interactive timesheet per employee. The morning shifts are highlighted with green colour, the afternoon shifts are highlighted with orange, the night ones with blue and the emergency shifts are highlighted with red colour.

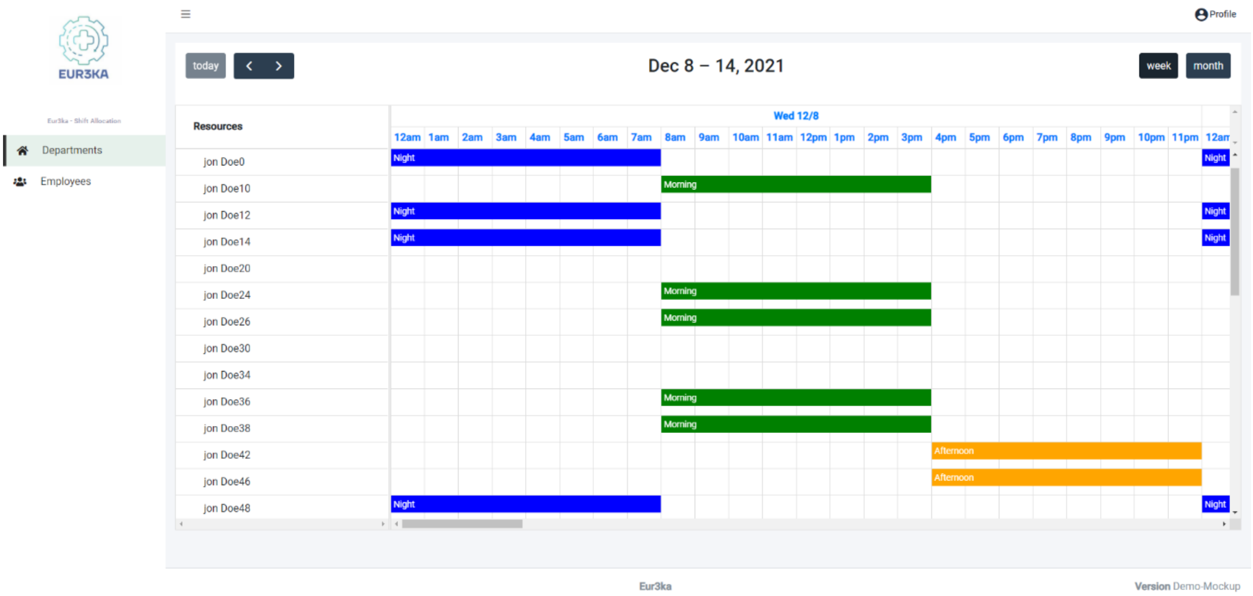


Figure 33 - Shifts plan overview per sector

5.1.4 Installation

The shift allocation is delivered as a service and can be hosted in any cloud provider as it consists of multiple components that can be deployed independently using docker-compose scripts. The installation process is automated using the Gitlab CI/CD [2] pipelines building the software directly from version control, publishing images and making the deployments to the cloud provider virtual machines. The shift allocation solution consists of multiple software components that are developed under different technologies and frameworks and are separated into 3 layers which implement the frontend the backend and the algorithm respectively:

- Frontend: The frontend software component is developed under Angular framework[3] and implements the logic that is presented in the previous section.
- Backend: The backend software component is developed under spring boot[4] framework and is responsible for providing data to the frontend and by exposing the following Rest APIS. The API documentation is available in the link bellow: https://eur3ka.shift-allocation.rid-intrasoft.eu/api/swagger-ui.html#/

[2] https://docs.gitlab.com/ee/ci/
[3] https://angular.io/guide/architecture
[4] https://spring.io/projects/spring-boot

Table 2 - Rest APIS Descriptions

REST interface	Description
/employees	Interface for inserting and retrieving new employees to the system, distribute them to departments and assign roles.
/sectors	Interface for retrieving sectors per department and inserting new ones to an existing department
/roles	Interface for, inserting and retrieving roles as discrete instances.
/reports	Interface for letting employees post events regarding any COVID19 incident and their availability to work.
/shifts	Interface for inserting and retrieving new weekly shifts per department sector.

- Algorithm: The algorithm software component is developed in Python programming language and is implementing the formulation and execution of the shift allocation problem. The algorithm provides Linear programming solutions by considering the following constraints:
  - Each employee must be assigned to exactly one shift and one sector
  - Each employee must work in exactly one sector per shift
  - Ensures that each employee that is selected for a specific shift is aligned with the sectors required qualifications. Employees are selected according their skills and the way they match with the sector's skill requirements. All shifts are 8-hour long by default but can be adapted according to the organization's time plan.

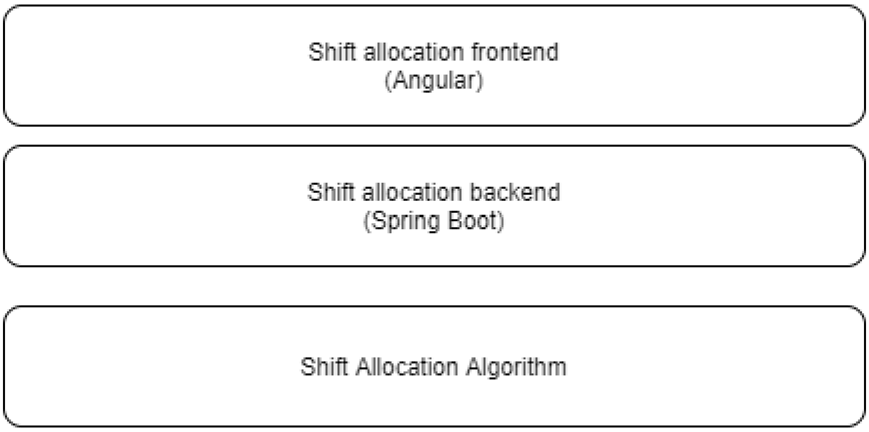


Figure 34 - Software components stack

The installation process is triggered by the CI/CD pipeline which includes the following steps:

- Build process: The process can be triggered manually or automatically if the source code is updated on GitLab version control. It performs automatically building, packaging and containerization of all components by downloading dependencies and third-party libraries. The process is tagged with the **build-job** acronym.

- Publishing software process: The process is triggered after the successful build of the previous step and is responsible for transferring and deploying the executables to the cloud provider. The publish process is tagged with the acronym **publish-job.**

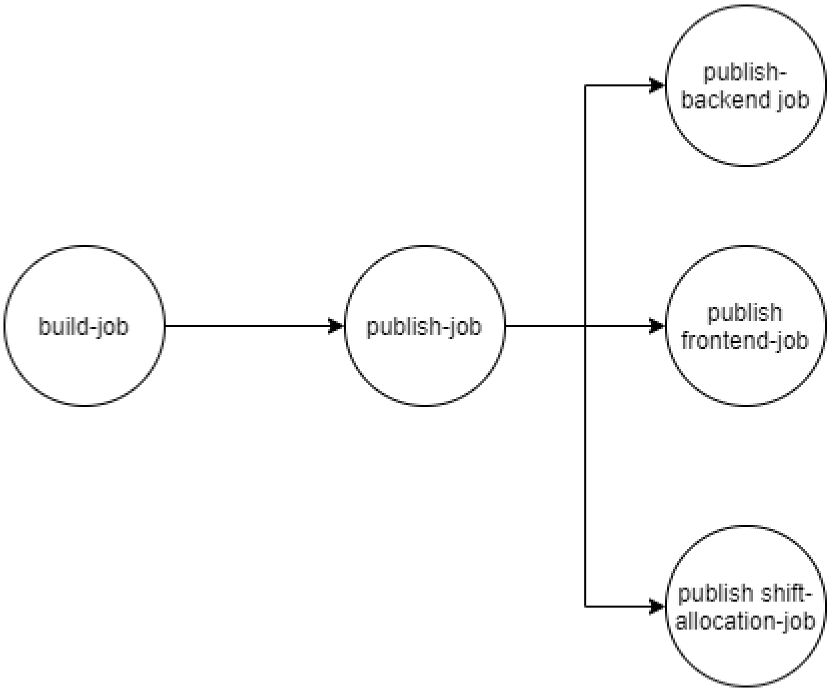


Figure 35 - CI/CD pipeline

- and is divided to subtasks for publishing the frontend the backend and the algorithm software components. The subtasks are tagged with the acronyms **publish-backend job publish frontend-job** and **publish shift-allocation job** respectively.

Each CI/CD pipeline step in order to build the individual software components is executing the docker-compose scripts define in the table below. The source code of the whole solution is available:

https://gitlab.com/intrasoft-rid-eur3ka/T4.6

Software Component	Installation Script
Frontend	`version: '3'` `#networks:` `#monitor-net:` `# driver: bridge` `services:` `  eur3ka-dashboard:` `    pull_policy: always` `    networks:` `      - backend_api_network` `    environment:` `      - SHIFTS_WEB_SERVICE_URL=https://eur3ka.shift-allocation.rid-intrasoft.eu/api`

	`` - SHIFTS_SOCKET_SERVICE_URL=https://eur3ka.shift-allocation.rid-intrasoft.eu build: . image: eur3ka-dashboard container_name: eur3ka-shifts-dashboard restart: always ports: - 4000:80/tcp networks: backend_api_network: external: true ```
Backend	``` version: '3' services: ShiftsServer: networks: - postgres_postgres - api_network - kafka_default build: . image: eur3ka-shifts:latest restart: unless-stopped container_name: eur3ka-shifts-service environment: - spring.profiles.active=prod - spring.jpa.hibernate.ddl-auto=update - spring.datasource.url=jdbc:postgresql://postgres:5432/shifts - spring.datasource.username=postgres - spring.datasource.password=rebecca - kafka.ip=kafka - kafka.port=9092 ports: - 8081:8081/tcp networks: postgres_postgres: external: true kafka_default: external: true api_network: driver: bridge ```
Algorithm	``` version: '3' services: optimizationalgorithm: networks: - kafka_default image: optimizationalgorithm:latest container_name: optimization_service build: . environment: - kafka_ip=kafka networks: ```

	`kafka_default:` `  external: true`

Table 3 - Software components installation scripts

5.2 Risk Assessment Services

The On-line Interactive Factory Risk Assessment Tool is going to have Risk Assessment along with other details, for example plant size, distance between workers, numbers of bathrooms.

After having the Risk Assessment created and details filled by the responsible, the techinician is going to analyse the risk taking in account the risk mitigation checking what is the probability of that risk occouring and what could happen if that occur.

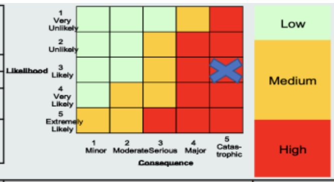
Our tool will use AI to gave recommendation/suggestion in order to have better results in the risk assessments and also, for example, if exists a reporposing and the distance between workers change it will suggest the risk that could have now. Of course this suggestion/recommendation will not replace the visit of a professional.

5.2.1 On-line Interactive Factory Risk Assessment Tool

The Risk Assessment Tool has the purpose to evaluate the risks of the repurposing of the reconfiguration of the production lines regarding COVID19.
The idea is to identify the risks of the new configuration taking into account the current guidelines and regulations for COVID19 mitigation. These guidelines shall then be updated according to future revisions. For that matter the European Guidelines[5,6] for COVID19 for work environments were analysed. On top of that the different countries rules for COVID19 were also analysed as well as different areas of operation.
Apart from the guidelines we also performed an extensive search of examples of risk assessment forms. Following are presented some snippets of examples of risk assessment:

[5] https://osha.europa.eu/en/publications/covid-19-back-workplace-adapting-workplaces-and-protecting-workers/view
[6] https://oshwiki.eu/wiki/COVID-19:_Back_to_the_workplace_-_Adapting_workplaces_and_protecting_workers

Assessment Title (Task, process, equipment or facility)	COVID-19		Task/ process owner	Site
Location	All sites	Date	Mar-20	
		Date for next review	Last reviewed 29/04/2020	
Prepared By (Team)				
		COVID-19 controls in line with government guidelines and site control measures and actions.		



Steps, parts or sections	Hazard	Effect (Who/what affected AND how)	Existing Controls (inc practices/ procedures)	Initial Risk			Additional Controls/Opportunities (inc practices/ procedures)	Residual Risk		
				Likelihood	Cons	Risk Level		Likelihood	Cons	Risk Level
GOV GUIDELINES	COVID - 19	Contracted COVID-19 or passing on the virus - all persons	1. Only go outside for food, health reasons or work (where this absolutely cannot be done from home). 2. Stay 2 meters away from other people. 3. Wash your hands as soon as you get home. (HR) have developed protocol flowcharts for employees and managers to follow with regards to actions to take. These have been communicated to all managers and employees.	3	3	Medium	Monitor Gov guidelines and Siemens Guidelines	3	3	Medium
		Contracted COVID-19 or passing on the virus - all persons	Symptoms. 1. A new continuous cough - this means coughing a lot more than an hour, or 3 more coughing episodes in 24 hours (if you usually have a cough, it may be worse than usual). 2. A high temperature - this means you feel hot to touch on your chest or back. 3. Shortness of breath	3	3	Medium	Follow current government guidelines if you suspect these symptoms.	3	3	Medium
Communications	COVID - 19	All COVID-19	SCC/ECC regular updates including strategic management, CV19 status and actions, CV- questions and answers. EHS Meetings to review the effectiveness of CV-19 controls. QMM regular CV19 meetings to review the Siemens and Government guidelines/compliance. Regular Siemens meetings. Compliance and strategy. Comms 20, ppt slides, notice boards, mental health, Q&A. HR and EHS on the ground - open door policy - emails etc. Noticeboards. Electrium/Siemens intranet.	1	3	Low	Monitor external communications	1	3	Low

Figure 36 - Siemens COVID-19 Risk assessment example (Siemens)

Voce	Attuato	In corso	Non applicabile	Note
Massimo utilizzo del lavoro agile per le attività che possono essere svolte presso il proprio domicilio				
Sospensione delle attività dei reparti aziendali non indispensabili				
Applicazione protocollo anticontagio				
Rispetto della distanza di 1 metro				
Uso della maschera quando non sia possibile rispettare la distanza di 1 metro				
Incentivazione delle operazioni di sanificazione dei luoghi di lavoro (anche utilizzando ammortizzatori sociali)				
Limitare al massimo gli spostamenti all'interno delle sedi di lavoro				
Contingentare l'accesso agli spazi comuni				
Differenziazione degli orari di ingresso, uscita e pause				
Affissione di cartellonistica anticontagio				
Eliminazione degli spostamenti tra aree di competenza diverse				
Verifica delle distanze di 1 metro tra un operatore e l'altro, in particolare tra un operatore e chi gli sta dietro				
Rispetto della distanza di 1 metro in reception, rispetto a chi viene accolto				
Eliminazione degli accessi dall'esterno o adozione della procedura di autorizzazione / anticontagio				

Figure 37 - Conflavoro Covid-19 risk assessment example (Conflavoro, s.d.)

Environmental Health Northamptonshire

COVID-19 Illness	
What arrangements do you have in place for managing illness and self-isolation notifications? What is your staff absence rate due to COVID-19? (%) Are all absences being recorded and analysed according to category? *(COVID-19 symptoms/household self-isolation/12 week isolation due to existing conditions etc.)*	
Do you have a return to work policy?	Yes ☐ No ☐ Documented? ☐
Do you stay in contact with your employees? Is their return to work monitored? Is dedicated medical advice accessible?	
Deciding on who should be at work	
What action have you taken to ensure that only essential staff are on site? Have you minimised staff numbers on site while continuing to operate safely and effectively? What measures have you put in place to monitor the wellbeing of people working from home? What equipment have you been able to provide staff to facilitate working from home? ***Notes:***	
Workplace social distancing	
Arrival & Departure	

Figure 38 - Environmental Health Northamptonshire COVID19 Risk Assessment (West Northamptonshire Council , 2020)

What are the hazards?	**Who might be harmed**	**Controls Required**	**Additional Information**	Action	Action by who & when?	Done Yes / No / Ongoing
Spread of Covid-19 Coronavirus	The following people may be harmed and measures taken to protect them: Staff Visitors and Customers to your premises Cleaners Contractors Drivers	**General – Management** 1) Information on Covid Control measure must be communicated to all staff, visitors and customers. 2) Staff (and others) should be regularly reminded of the Covid control measures in place and the need to follow all of the relevant procedures. 3) Managers or appointed 'covid marshals' shall check to ensure that appropriate procedures are being followed and that facilities provided are maintained. **Hand Washing** (For more information see - https://www.hse.gov.uk/coronavirus/c	To help reduce the spread of coronavirus (COVID-19) reminding everyone of the public health advice - https://www.publichealth.hscni.net/news/covid-19-coronavirus Posters and signage to be erected in prominent locations. Posters, leaflets and other materials are available for display. https://www.gov.uk/government/publications/guidance-to-employers-and-businesses-about-covid-19 Regular communications including tool box talks and tem briefs to include covid reminders.			

Figure 39 - HSENI Covid19 Risk Assessment example (hseni, 2021)

Hazard	What could happen?	Likelihood of occurrence	Consequence of occurrence	Inherent risk score (if no measures)	Proposed control measures	Residual risk score	Implemented by	Date implemented	Date reviewed
Therapist exposed to droplet transmission from a symptomatic client	Treating therapist, other therapists and staff could become infected with COVID-19 (Could result in serious illness and death)	Unlikely (Rating will vary according to recorded rate of local community transmission)	Moderate – Major (Depending on therapists' and staff members' personal circumstances and health status)	High	• Pre-screen to determine if client is experiencing any primary or secondary known symptoms of COVID-19, currently or 14 days prior. • Check temperature prior to entry to clinic with both therapist and client wearing mask. • Exclude client from treatment if any symptoms are declared or if temperature is outside acceptable range. • Instruct client to seek testing. • Exclude any symptomatic individual for minimum 14 days or until 2 consecutive negative tests. • Provide hand sanitiser at entry. • Display WorkSafe Australia signage. • Disinfect surfaces that may have been touched by the client.	Low			
Therapist exposed to droplet transmission from an asymptomatic client	Treating therapist, other therapists and staff could become infected with COVID-19 (Could result in serious illness and death)	Unlikely (Rating will vary according to recorded rate of local community transmission)	Moderate – Major (Depending on therapists' and staff members' personal circumstances and health status)	High	• Check temperature prior to entry to clinic with both therapist and client wearing mask. • Encourage client to wear a mask when entering the facility and during pre-treatment and post-treatment discussions. • Encourage client to wear a mask for all treatment conducted in supine or side-lying positions. • Discourage client from excessive talking during treatment session. • Apply standard precautions and educate client on hand hygiene, cough etiquette. • Disinfect surfaces that may have been touched by the client. • Stagger client arrival times. • Minimise client on-premise waiting time and activity. • Facilitate off-site payment process. • Minimise need to interact at reception. • Install perspex barriers around reception area. • Observe social distancing between therapists and staff members. • Implement traffic control for non-treatment areas, hall, stairways, shared egress.	Low (Assumes that there is no community transmission occurring in local area)			
Therapist working whilst experiencing possible symptoms of COVID-19	Clients, other therapists and staff could become infected with COVID-19 (Could result in serious illness and death)	Likely	Major-severe (Depending on clients', therapists' and staff members' personal circumstances and health status)	Extreme	• Screen temperature before treating clients. • Seek medical attention if displaying any primary symptoms. • Develop and implement communication strategy to notify clients and cancel all appointments if therapist experiences any symptoms. • Observe social distancing between therapists and staff members. • Implement traffic control for non-treatment areas, hall, stairways, shared egress.	Medium			

Figure 40 - Amt.org.au COVID19 Risk Assessment (AMT, s.d.)

Sample Risk Assessment Form						*Activity/Job/Task: Working in the main office, routine activities*				
Prepared by		Date Prepared		Document No.		Revision No.		Revision Date	Dept./Location/Area	
Jane Doe		May 20, 2020		123.123						
Uncontrolled Risk of Hazard						**Controlled Risk of Hazard**				
HAZARD		Workers affected (#)	Likelihood	Consequences	Initial Risk Rating	**CONTROL MEASURES**		Likelihood	Consequences	Residual Risk Rating
B	Biological					EL	Elimination			
C	Chemical					S	Substitution			
P	Physical					EN	Engineered			
Ps	Psychosocial					A	Administrative			
						P	PPE			
B	SARS-CoV-2	All staff (18)	Most Likely	Extreme	High	EL EN EN A A PPE	Working from home Barrier for reception desk Single occupancy office rooms COVID 19 Policy, Signage Sanitization Program N/A	Rare	Extreme	Low

Figure 41 - Manufacturing Safety Alliance of BC Risk Assessment (Manufacturinsg Safety Alliance of BC, s.d.)

The expected result is to have an online platform/service, which then ask the respondent, questions about the new repurposing, regarding the numbers of workers, size of spaces, facilities, etc., and compares the answers with the guidelines and regulations.

Some platforms apart from the usual ones (Microsoft Forms, Survey etc.) for creating surveys were tested, the main ones being:

- LimeSurvey CE– Is open source and allows for self-hosting built in PHP. It is very customizable as it only allows for the use of pre-defined templates. The forms can be shared. It has features such as branching and multiple question types. The official website can be found at https://community.limesurvey.org

- Ohmyform – A free and opensource form builder with sharable capabilities but less customizable and no branching features. The official website can be found at https://ohmyform.com
- Docassemble – It is open source allows self-hosting and has inbuilt document assembler which can be parameterized depending on the answers given from the respondent. It also has the capabilities to send communications. It is also has highly customizable. The forms are sharable. The official website can be found at https://docassemble.org

With that information the tool then analyses where are and the level of the risk, the mitigation measures that can be applied and the residual risk after the measures applied. These analysis will also be using AI methods and is going to provide suggestions/recommendations on how to handle the risk or if a reporposing happens chaning some details of the factory changes it will suggest the new level of risks.
In the end the tool will deliver a document with all the information that was assessed, and that can be printed and fixated into the respective factory.

5.3 Repurposed Production Line Virtual Commissioning

Commissioning of a manufacturing system can take up to 15-20% of the total delivery time of an automation system project. Different studies have pointed out that most of the time (2/3) is used on fixing software errors discovered during the systems integration, errors which usually are corrected on the fly to deploy and start the production with the new manufacturing system.

Quick fixes completed on the fly can facilitate starting up the system and production ramp-up. Still, the quick fixes done during the commissioning phase can generate later operational and production problems when the system is in operation, resulting in later repercussions in production quality, systems maintenance, and even failure.

Virtual commissioning technologies changed how manufacturing lines were placed into production, reducing commissioning times, avoiding costly mistakes, and accelerating production ramp-up. Compared with traditional workflow (see Figure 42), the time required to start production is reduced considerably.

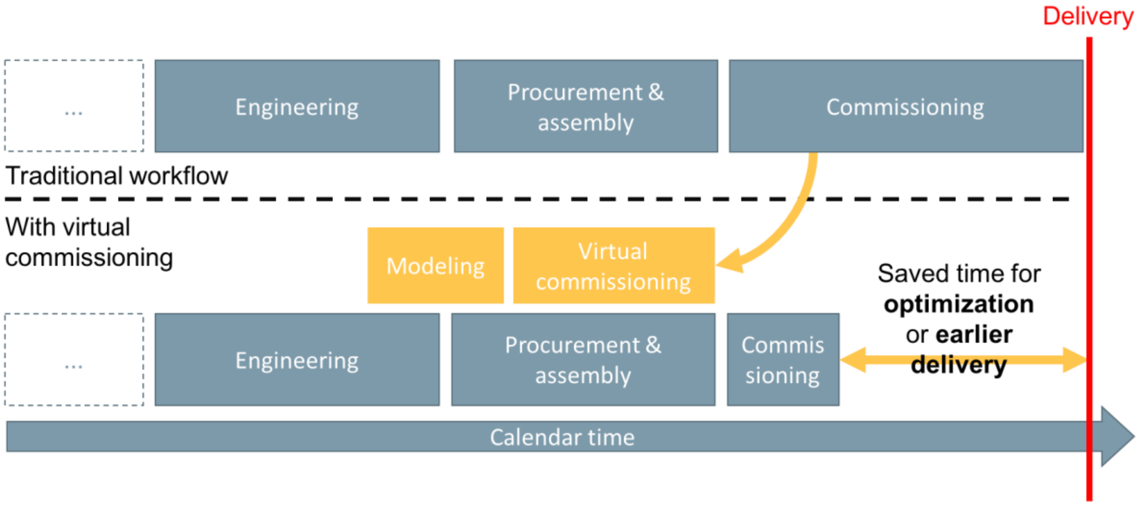


Figure 42 - Timeline comparison of commissioning of a manufacturing system with and without virtual commissioning [5]

Within Eur3ka projects, virtual commissioning technologies are further developed within new domains, particularly medical and pharma, to carry commissioning tasks to an earlier stage of the repurposing project (Figure 42), even from the engineering phase. In this way, all the commissioning tasks which can be validated using virtual commissioning technologies are moved to an earlier engineering stage of the project away from the critical phase of the commissioning.

Digital technologies such as 3D simulation and visualization demonstrate an essential role in virtual commissioning. The 3D model simulation library, which is being developed within Eur3ka, can be utilized from the concept phase combined with 3D simulations to be further developed during the engineering stage to mirror the real production line. The availability of AI tools to support the concept phase facilitates and accelerates the initial design of the production line. Requirements are parameterized to find the most efficient solution available between the different system providers available in the electronic catalog. The engineering phase is crucial as design errors can be identified in the virtual environment even before the real system has started to be manufactured, avoiding costs and delays. The simulation can be used simultaneously with the procurement and assembly to verify the design and test the control and robotic systems. Connecting the real control systems gradually, as they become available, with the 3D virtual models of the production line, the design can be validated even before the manufacturing system has been built.

Virtual commissioning is reported in different studies ([5],[7]) to have many benefits if it is correctly integrated during the engineering phase. It reduces the total engineering time and prototype waste, causing less expensive errors, as they are detected earlier. The quality of the software is significantly increased. Based on the study presented in [5], we can expect that within Eur3ka, using virtual commissioning quality can be improved up to 90%, and commissioning time reduced around 75%.

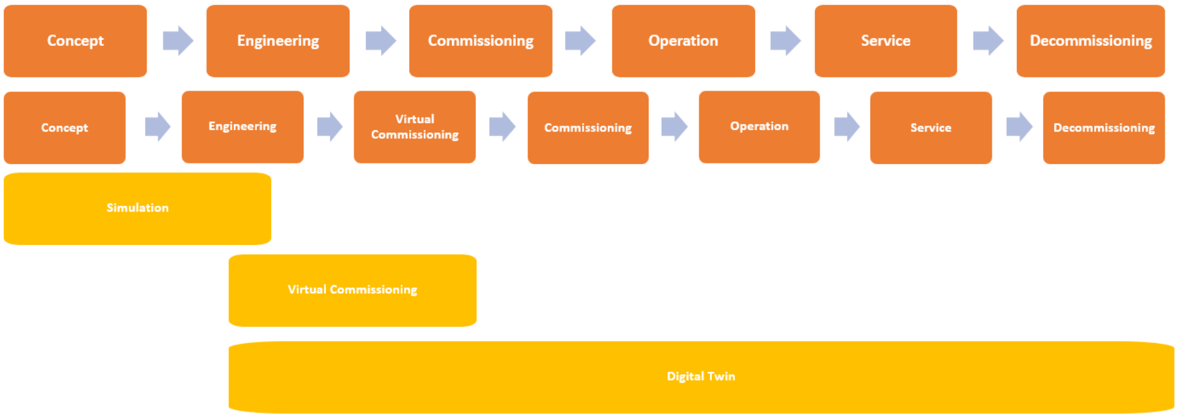


Figure 43 - Production line life cycle before introducing virtual commissioning technologies and after virtual commissioning

The utilization of the latest ICT technologies pushes virtual commissioning beyond the validation of the production line at the equipment, control, and robotics level. Latest ICT technologies extend virtual commissioning, allowing the virtual environment interconnectivity with systems from different levels such as SCADA (Supervisory Control and Data Acquisition) and MES (Manufacturing Execution System) systems. Furthermore, the communication technologies enable the digital twin deployment (Figure 43).

The digital twin combines a computation model provided by the 3D simulation and the real production system. Digital twins can be used for various purposes, such as production planning during operation runtime, design and testing adjustments, and diagnostics. Additionally, they can provide accurate representations mirroring the real system during operation [8]. Within Eur3ka, the interfaces will be extended to communicate the digital twins provided by the 3D environment provided by Visual Components 4.0 with the AI- tools developed within the project to enhance the production system.

Digital twins provide the platform to improve productivity and analyse current production scenarios while runtime operation, validating possible alternatives without stopping production. Code testing and debugging before updating the production equipment. Validation of production scenarios, including the introduction of new product variants. It can be also used in the training of supervisors and equipment operators[8].

Commissioning a new manufacturing system is challenging, facilitated with digitalization technologies such as 3D simulation, virtual commissioning, and digital twins. Production repurposing of an existing production line is even more challenging that can take advantage of the same digitalization technologies to facilitate it.

Repurposing an existing production line entails constraints as the existing resources must be reused as much as possible. The utilization of digital twins of the current production line can facilitate repurposing. Figure 44 depicts the repurposing workflow as the operation data from the production line can be reused in the repurposing process. Further development of the AI solutions can extend the capabilities while the concept phase accessing the availability of equipment from different providers delivery times and adaptability to the new production requirements while maintaining costs and realistic commissioning times.

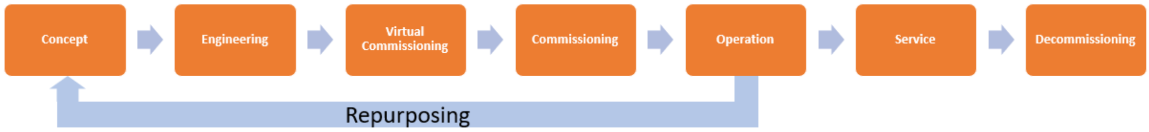


Figure 44 - Repurposing of an existing production line

5.4 Potential use of AI in Production Repurposing and Testing

The Eur3ka RA (Reference Architecture) makes provisions for digital components that implement BigData analytics functions, including Machine Learning (ML) and Artificial Intelligence (AI). The use of such modules is not mandatory for the implementation of Eur3ka scenarios, yet they can boost automation and intelligence of the manufacturing repurposing solutions. Moreover, the deployment and use of AI/ML in manufacturing repurposing scenarios is currently very challenging due to the lack of appropriate datasets from past disruptions of production and shocks in the supply chain. For instance, there are very few data about supply chain behaviour during pandemics and healthcare crises that could be used to train ML modules in Eur3ka. Nevertheless, in the scope of some Eur3ka trials the potential of AI to provide value added functionalities has been identified.

As a prominent example, the training of an ML module (I.e. a neural network) for automatically identifying and specifying repurposed product configurations is considered in the SEAC face masks pilot. Specifically, the module could be used in the scope of product testing to correlate geometrical features to the expected test results for different models, shapes, and sizes etc. of the product. The problem involves generation of data in order to build on a set of historical information on tests done on FF masks in SEAC premises. In particular, SEAC considers equipping the CO2 test machine and the ANSTI test machine that are used in the pilot to automate the collection of data during mask quality tests. The tests are aimed at checking new products, with emphasis on three parameters:

- Residual CO2 inside the mask chamber after exhalation;
- Tightness of the FF mask on the user's face;
- Respiratory effort for the user.

The first and second parameters are measured by the CO2 test machine, while the third one by the ANSTI machine. Then, for each FF mask tested by each of the machines, the following data will be bundled into a data object:

(A) From CO2 test machine: An identifier code of the FF mask tested; An anonymous identifier of the operator; The test date and hour [UTC, YYYY-DD-MM HH:MM:SS]; The test duration [s]; Inhaled air mixture [l]; Breathing cycle time [s]; CO2 inlet level in the air mixture [%]; CO2 residual level [%]; Vacuum level [bar];Vacuum duration [s**].**

(B) **From the ANSTI test machine**: An identifier code of the FF mask tested; An anonymous identifier of the operator; The test date and hour [UTC, YYYY-DD-MM HH:MM:SS]; The test duration [s]; Room temperature [°C]; Water temperature [°C]; Exhale temperature [°C]; Breathing cycle time [s]; Tidal volume [l]; Breath rate [bpm]; Ventilation rate [lpm];

Inhale pressure [mbar]; Inhale Pos pressure [mbar]; Exhale pressure [mbar]; Ext Work of breathing [J/l]; Inhale Work [J/l]; Pos inhale Work [J/l]; Exhale Work [J/l].

The development of the neural network will aim at providing an automated classification of the test results, considering the above listed parameters as inputs. This will accelerate the quality testing process, while driving the extraction of knowledge on which parameters ("features") are likely to lead to products of acceptable quality. During the first reporting period of the project, SEAC has deployed the IoT sensors and devices, yet not adequate and properly labelled sets of data have been yet collected to enable the prototyping of the neural network module.

6 Reliable Repurposing of Production Line Services

6.1 Quality Control Design Tools

In Eur3ka, setting up a quality control system for mass production for complex PPE/CCE compliant with medical regulations quality standards is non-trivial due their complexity. Several new tests may be necessary and significant resources are required to develop process documentation, establish safety controls and verify the quality of supplies. It is clear that scaling up production is not simply a technological challenge, but requires new organisational capabilities, from product design and manufacturing to supply chain governance, regulation and testing.

Based on this scenario, and in order to ensure the quality of products and services, Eur3ka will follow a Quality Management System (QMS) approach for having a systematic process for achieving the quality objectives when production lines repurposing will be required. Therefore, the organisations shall establish, document, implement, maintain and continually improve their own quality management system.

A QMS covers different phases. First, a quality planning establishes the quality goals by the organisation that helps in developing product and process features, defining and developing methods and providing the methods must be developed, and adequate equipment must be available to make the product match its design specifications. After the planning phase, quality control takes over. Here, the goal is to run the process effectively such that the plans are enacted. Through the control will attempt to identify the cause behind this abnormal variation. Upon identifying the cause, remedial action will be taken to bring the process back to control. Finally, the continuous improvement of the product and the process, usually require action on the part of upper and middle management, who deal with such actions as creating a new design, changing methods or procedures of manufacturing, and investing in new equipment.

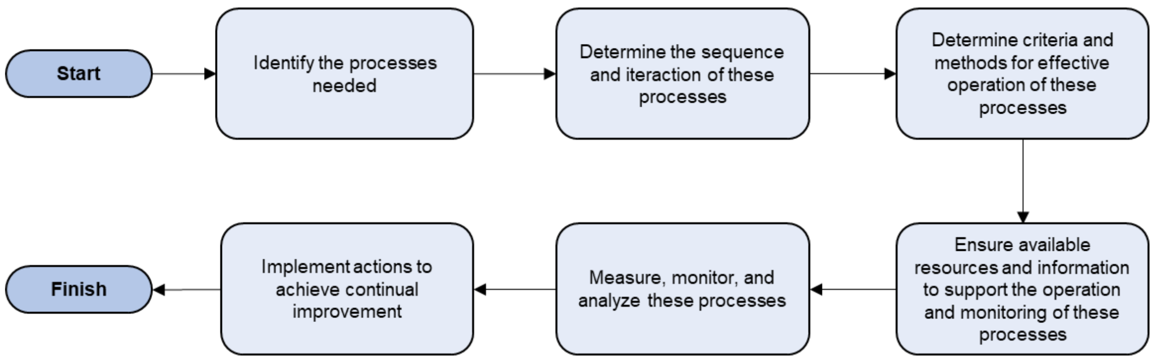


Figure 45 - Quality Management System (QMS) establishment

Once the quality plan is established, the quality control has the responsibility of defining and coordinating a series of steps:

1. Identify and choose control subjects, these are the characteristics of the product to be controlled so that it conforms to the design requirements. The selection is made

by prioritizing the important characteristics that influence the operation or appearance of the product.

2. Choose the units of measure. Depending on the quality characteristics that have been selected for control, the appropriate units of measure should be chosen.
3. Set goals. Operational objectives are created so that the product or service meets or exceeds customer requirements.
4. Create a Sensor. To collect information on identified quality characteristics, automated equipment or people acting as auditors or inspectors are integrated into the system. In this aspect, systems or databases that automatically track measurements of quality characteristics could be consider sensors.
5. Measure actual performance. This phase of quality control is concerned with the measurement of the actual process output. Measurements are taken on the previously selected control subjects (or quality characteristics) and the frequency of monitoring and measuring must be decided. Such measurements will provide information on the operational level of the process. Interpret the difference. This involves comparing the performance of the process with the established goals.
6. Take action on the difference. In the event that a discrepancy is found between the actual output of the process and the established goal, remedial action needs to be taken.

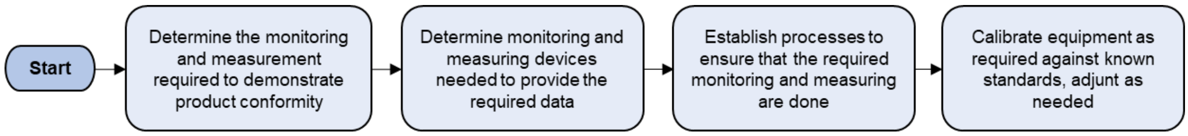


Figure 46 - Control of Monitoring and Measuring equipment

Eur3ka will leverage advanced collaborative platforms and quality data spaces that enable faster, concurrent and cooperative means of addressing quality issues, which is crucial to ensure that fast repurposing can be achieved. In this regard, Digital Lean Zero Defect Manufacturing (ZDM) process configuration and Digital Quality Control (DQC) methods based on QU4LITY & Boost 4.0 platforms are considered. This, combined with the development of the quality data space and the deployment of the M3 platform for secure data exchange and remote programming of quality control equipment for the automotive industry's complex fan and face shield reuse manufacturing lines, will afford the quality control.

6.2 Flexible Production Line Design

The COVID19 pandemic has stressed the need to speed up industrial transformation, improving the flexibility and resilience of the manufacturing system. As a result, many companies are redefining their strategies and investment plans for the future, following well-established trends that have gained prominence during the pandemic. The majority of the industrial entities are now oriented towards improved flexibility. The major uncertainties connected to the current context highlighted the inefficiency of rigid production systems unable to accommodate demand fluctuations and an excessive reliance on the supply chain. The design of a flexible production line interconnected with the manufacturing ecosystem should consider the following aspects:

- **Modularity**: flexible lines usually involve dedicated machine tools and automatic logistic devices. CNC machining centres and robotics cells are the most significant components given their high adaptability.
- **Information flow**: the availability of real-time data is a necessary condition for coordination and process optimization, both within the individual enterprise and throughout large networks improving the resilience of the supply chains. Key technologies in this view are Internet of Things (IoT) and Cyber Physical Systems (CPS), which enable the communication between machines, humans and products, powered by 5G technology.
- **Remote operations**: condition monitoring, predictive maintenance, traceability and digital twinning have already widely proven their potential. Moreover, the conception of the relationships among people and companies has also drastically changed. Indeed, the development of collaborative design platforms, remote operations and support tools, production and distribution monitoring, virtual commissioning, data-based planning, and cloud manufacturing are gaining a central role in the idea of the future industrial framework.
- **Data valorisation**: the relevant progress in Artificial Intelligence (AI) algorithms have enabled the application of the intelligent manufacturing concept, extracting value from the huge amount of collected data.
- **Up/re-skilling**: during a repurposing process the up/re-skilling of the employees has to be considered. A careful evaluation of the business proximity between the current needs and the original competencies is crucial in the decision process. In this context, training tools, such as augmented and virtual reality relying on digital twinning technologies, may support employees accelerating production line modifications.
- **Flexible planning**: the current period of uncertainties and the required flexibility has drawn attention to sophisticated planning and decision support tools. These tools could be beneficial at several corporate levels. Indeed, simulations such as what-if analysis are deemed more than ever essential to identify the best strategy given a long-term uncertainty.
- **Business models**: the flexibility concept opens the way to the application of innovative business models and alternative commercial solutions, such as Manufacturing as a Service and rental solutions. These approaches meet the current lack of liquidity and resources to make new investments and allow several companies to expand their market.
- **Automation:** quick reconfiguration of testing facilities and machines in a multipurpose production environment can be one of the keys to face an emergency situation, where the manufacturing context must switch between products and models. Design and integration of automation systems can be adopted as services to allow a high level of flexibility.
- **Decision Support:** data produced during production and testing of products thanks to IoT and automation solutions will feed a production historical database. AI methods represent then an asset to help production managers to reconfigure parameters and key aspects of manufacturing (product models, size, components, materials to be used, production techniques, etc.), towards a full optimization of testing results and product performances.
- **Best practices:** in case of innovative products where a lack of legislation and regulations can be found, the automation of facilities and data valorisation can be used to define a database of references for the product features and performance. In such cases, production and test data can be processed to define

some recommendations towards policy makers and standardization bodies, to pave the way for defining a European regulation.

6.3 Production Repurposing & Resiliency Maturity Assessment Services

Global challenges such as the worldwide spread of COVID19 challenged manufacturers' conventional production planning practices. Challenges that have required adjustments in the production organization have been necessary to adapt production plans, work shifts, and the overall production logistics to adjust to the changing production requirements. The utilization of digitalization technologies, mainly 3D simulation and visualization, virtual commissioning, and digital twins (see Section 5.3), have facilitated the adaptation of production to respond to the changing production requirements [10].

Production repurposing has been introduced during the pandemic as a fast response to manufacturing products required to face the global spread of COVID19, such as hand sanitizer, personal protective equipment (PPE), and face shields and masks, as well as other medical equipment such as ventilators. If the utilization of digital technologies such as digital twin and virtual commissioning during the pandemic supported the fast adaptation of production, the same technologies supported the production repurposing.

While production repurposing has all the challenges of commissioning a new manufacturing system, it has additional challenges as it should be adapted to existing production and must target the mitigation of production risks. The availability of production data of the existing production line facilitates the creation of the digital twin that will support the process presented in Figure 44.

The digital twin facilitates the concept development of the new production requirements, showing the feasibility and necessity of equipment adaptation. Virtual commissioning is simplified as the existing digital twin can be utilized to accelerate ramp-up operation.

6.4 Cognitive Digital Twin

Digital technologies are continuously enabling the transition to the Digital Twin, thanks to the modelling-simulation process, which can build a bridge between the physical and virtual worlds, bringing innovation with great efficiency and drastic reduction of waste. So that the digitalization appears the solution to cover the entire lifecycle of the supply chain overcoming the increasing demand of process reliability and standardization systems, with the possibility of optimizing the efficiency, flexibility and time-to-market. Each stage of the production process can be impacted by the digital transformation. Starting from a proper digital background with the support of AI and machine learning model, the cognitive digital twin takes place. In the complex context of the manufacturing industry typically there is a wide range of different possible constraints such as the interoperability among components, data access and exchange with third parties, many standards and protocols used, then the cognitive digital twin can support the overcoming of that impediments, improving at the same time the efficiency, performance and quality control of the real plants. The Digital Twin approach must not be considered only a simulation representing the real world, but actively accompanies the product through the whole chain allowing also the continuous monitoring and control in complex production environments.

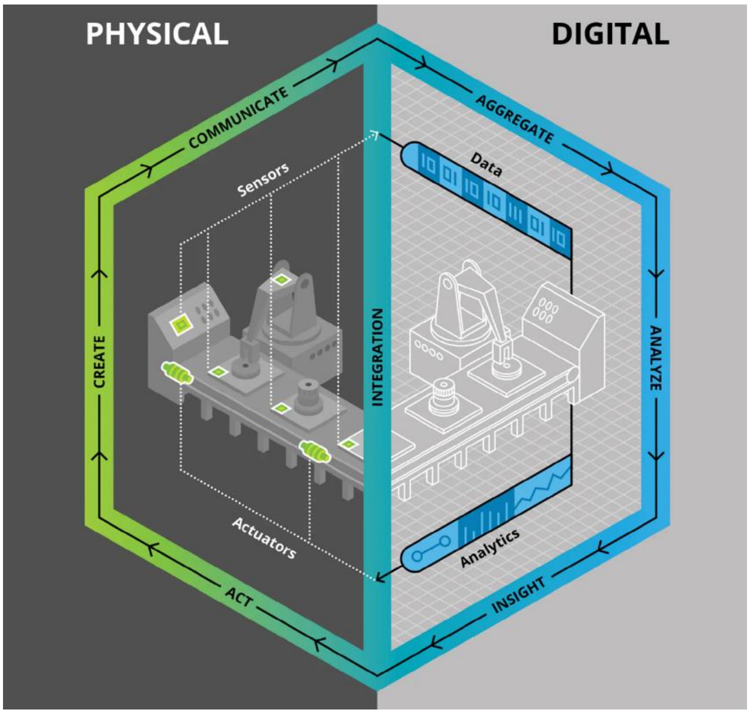


Figure 47 - Cognitive Digital Twin

An example of one the main challenges in this field is to enable efficient monitoring and control in cases when the production or environments are complex. The basic elements of process monitoring and control loop, including the models which can be used for supporting this task cannot be solved easily using nor traditional techniques from process monitoring neither solely by using advanced AI techniques. This problem requires a better understanding of the underlying data and processes, their contexts and their dynamics, similarly how human cognition is building a superior situational understanding and reasoning, even in very ambiguous cases. Therefore, in a cognitive application, there is a need for monitoring a broader context where the data is collected and processed in, as well as for a deep multivariate analysis of the variation in data, to be able to detect and react properly to some abnormality/unusual ties in the system behavior.

6.4.1 Interoperable Digital Twins: Asset Adminstration Shell (AAS)

Industry 4.0 aims to create value through the cross-manufacturer exchange of information with industry-neutral standards for communication, services and semantics. The key tool for meeting this requirement is the Digital Twin. An asset is an object that is to be integrated into the information world of Industry 4.0. There is a large range of possible assets – from machines and their components, supply materials, products and software to documents such as plans, contracts or purchase/service orders.

A Digital Twin (DT) is a Digital representation that’s sufficient to meet the requirements of a set of use cases (Industrial Internet Consortium (IIC) & Plattform I4.0). A digital representation is information that represents characteristics and behaviors of an entity (asset). According to the approach taken by IDTA (Industrial Digital Twin Association), the Digital Twin is, contrary to some interpretations, not a realistic virtual image of an object but rather a data image of an asset. An Interoperable Digital Twin represents data of an asset using industry-neutral specifications or standards acting quite similar to a USB connector which works in multiple applications irrespective of manufacturer because its standard is defined.

The Asset Administration Shell (AAS) is the implementation of the Digital Twin for Industry 4.0 defined by the Reference Architectural Model for Industrie 4.0 (RAMI4.0). The AAS realises the concept of Digital Twins of industrial assets – in the context of the Industrie 4.0 – and establishes the cornerstone for interoperability within industrial environments. The AAS consists of a series of submodels that describe all the data and functions of a particular asset – such as characteristics, properties, states, parameters, measurement data and capabilities. The AAS makes it possible to use different communication channels and applications and connects objects to the networked, digital and decentralised world.

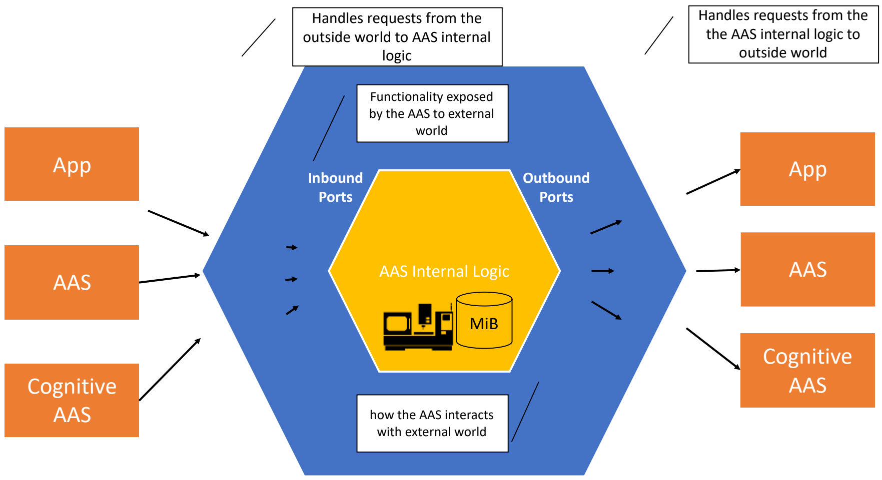


Figure 48 – Asset Administration Shell organization in hexagonal architecture representation

In the recent period several Open Source implementations of AAS-based solutions are being developed, and among them we may mention NOVAAS. The NOVA Asset Administration Shell (NOVAAS) is an open-source reference implementation and execution environment of the Asset Administration Shell (AAS). NOVAAS is an Asset Administration Shell that enables interoperable digital twins of industrial systems by providing an intuitive and standards-based environment. NOVAAS is a full-featured solution for managing assets and supporting automation processes. NOVAAS provides automatic configuration and integration with IIoT platforms, so that users can focus on higher level application development, instead of wasting time on configuring lower level systems provided by third party vendors.

NOVAAS enables the creation of Digital Twins at scale by providing a consistent way to organize your assets and to manage connections between the Digital Twin and your organization's asset data. NOVAAS is a new age IT solution that takes extensive use of internet-based technologies and standards, no-code / low-code development paradigm, cloud-native tools and technologies and more. NOVAAS is an open-source component that works with any implementation of the Digital Twin workflow, including those powered by Polyverse, Infra1 and Afero.

7 Conclusions and Future Outlook

This deliverable has provided, in-line with the Eur3ka strategy, a pool of services for manufacturing response, with the goal of rescuing the supply chains due to the recent events that disrupted production operations. In this kind of situations like COVID19, that could happen also in the next future for any reason, Eur3ka project will raise robustness, redundancy, resourcefulness, response, and recovery against them. As described in this document, most of the attention was focused on the cross-sectorial supply network, to ensure the resilience and the dynamic configuration of that based on the production capabilities, a smart search engine to match medical product manufacturing specifications and Eur3ka manufacturing network resources, a way to guarantee the production continuity respecting at the same time security needs and finally the services useful to obtain flexible manufacturing automation and products.

The process started from a first mapping of the ongoing development of the assets mapped on the Eur3ka Reference Architecture (see chapter 2), where the main pillars were the 4 Grand Scenarios that have driven the architectural design, taking into consideration also the inputs coming from D3.1. A significant part of the deliverable is devoted to presenting the current status of development, not the final result at all, at M12 in order to define the final results as an update in the D4.4. The outcomes will feed D3.2 with the purpose of refining, accordingly with the result of the development, their plug and response services.

In the following table the status related to each technology/result with the relative explanation of the percentage completion.

Table 4 - Technology Implementation Status

Technology or Result	Status (percentage)	Rationale
Manufacturing Repurposing Best Practices (ETZH, BRAIN)	100%	We collected case studies and the targeted case companies provided their best practices concerning manufacturing repurposing. No impediment was encountered.
IDS for Manufacturing Repurposing (ATOS, ENG, INNO, IDSA)	100%	A connector has been developed for object exchange to be printed in the 3DP network with a first implementation in a local network of a pilot.
Additive Manufacturing Network (SIEL)	100% (first iteration) Second iteration ongoing	During first iteration a number of API have been developed in order to allow programmatic interoperability to non-core components (e.g. Certified Assets Catalogue).

		Second iteration relates to interoperability with SMMA services for supplier selection.
Eur3ka Certified Assets Catalogue (SIEMENS, INNO, SQS, ENG,…)	100%	Shown in the Mid Term Review with uploaded products.
Smart Supply Chain Matching and Mediation Services (SMMA) (FHG-IOSB)	100% (first iteration) Second iteration - ongoing	The first iteration of the SMMA includes the specification of the architecture, the setup of the development and test environment with multiple factories, each represented by a connector, and the development of an initial prototype. The prototype was considered only one constraint and did not provide any configuration options. However, it was already integrated with the SFW. Based on the lessons learned from this initial development, the architecture was refined and is currently being implemented in the second version of the SMMA. The second version will extend the 1st version with additional functionalities and improve usability. It will provide support for multiple constraints simultaneously and include many configuration options (e.g. for sorting algorithms, for constraint weighting, etc.). On the factory side, it will provide an AAS template for representing constraints. To enable the use of any AAS in an EDC connector without manual effort, the AAS extension of the EDC will be applied. In addition, the SFW connector where the SMMA is deployed and all factory connectors will be the EDC connectors to ensure the use of latest IDS technologies.
Semantic Modelling and Interoperability Services (UiO)	90%	Revisions in the documentation will be performed based on the

		comments from the review meeting.
Medical Products Certification Services (SQS)	100%	One of the elements introduced by SQS in their platform Q-Med-Tech. Implemented.
Factory Risk Assessment (UNP)	40%	The On-line Interactive Factory Risk Assessment Tool is currently able to create the risk assessment templates.. The future version will be able to receive input from the responsible and using AI mechanism it will gave suggestions about what they should do with the risk.
COVID19 Aware Shifts Scheduling (INTRA)	100% (first iteration) Second iteration ongoing	As demonstrated during the technical review of the project (May 5th, 2022) a working version of the shifts allocation tool has been developed, considering the structure of the production and the shifts. The second iteration of the development is aimed at fine tuning the initial prototype, as well as augmenting it with more features (e.g., regarding the employees' skills). In this context, the relevant comments received by the reviewers will be considered and implemented as well.
Situation Awareness Service (ENG)	70%	The component has been customized in order to support the SEAC pilot. In the next week it will be improved, covering further requirements (real sensors data).
Manufacturing Repurposing Skills Framework (POLIMI)	100%(First iteration - up to M18) Second iteration – After M18 - ongoing	The assessment model firstly has been developed based on scientific literature and then it has been refined and improved thanks to the interactions with the industrial partners.

Virtual Training and Remote Support (VIS)	100% for the PoC Defining requirements for the pilot implementation	The first implementation deployed have been focused in a generic case for the pharma system. Pilot requirements for training and remote support are currently work in progress.
Digital Lean Quality Management (INNO, ATOS)	65%	The Guide to assist Eur3ka organisations (pilots) in the implementation of a quality management system (QMS) for the medical and medical devices sector in accordance with ISO 13485:2016, which allows them to be aligned with the with medical device industry regulations.
M3 Workspace (INNO)	100%	Developed with the information exchange framework implemented within the platform and fully functional.
M3 Trusted IDS Connector(INNO)	100%	Connector developed and implemented.
TRUE connector (ENG)	60%	The connector has been aligned to the last IDS Information Model. Contract Negotiation is fully supported as well as the resource managament. In the next months, an open-source usage control framework will be integrated.
Visual 4.0 Platform (VIS)	100% POC (M12). 40% Pilot implementation	The simulation libraries developed for the POC (M12) have been implemented and tested. Work has been initiated for the development for the pilot with the requirements and the first prototypes.
Remote Manufacturing Support Service (VIS)	100% POC (M12). 75% Pilot implementation	The POC (M12) has completed the implementatation of the remote manufacturing support. This work is partially used in the pilot implementation accelerating its deployment.

Workforce Training and Skills Development Services (POLIMI. VIS)	100% POC (M12) 60% Pilot implementation.	The POC is completed, and compiling training courses list (training activities list) is on-going activity.
Financial Impact Assessment (POLIMI)	100% (first iteration- up to M18) Second iteration – After M18 - ongoing	The assessment model firstly has been developed based on scientific literature and then it has been refined and improved thanks to the interactions with the industrial partners.

In conclusion, the final result obtained in D4.4 will support also the WP5 tasks to improve the trial handbooks.

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