# Data spaces for flexible production lines and supply chains for Resilient manufacturing

## Challenges in modern manufacturing value chain

Today, the manufacturing sector is significantly driven by globalisation, automation and digital technologies. Global manufacturing networks are often distributed across continents, exposing them to a multitude of vulnerabilities. Supply chain disruptions, whether caused by pandemics, geopolitical conflicts, natural disasters or cybersecurity breaches, can severely impact production timelines and the availability of critical resources. Such disruptions reveal the fragility of existing systems and the need for proactive, flexible responses that go beyond traditional risk management practices.

However, companies need to consistently deliver high-quality products while also minimising non-value-adding activities. So, how can manufacturers manage and quickly recover from disruptions? And how can supply chains become more resilient, making the manufacturing industry more flexible? The European research project Flex4Res addresses these questions by providing an open platform for secure and sovereign data exchange along the supply chain, supporting the reconfiguration of production networks. In a world of rapid technological advances and increasing global uncertainties, Flex4Res is driven by the need to transform the resilience and adaptability of manufacturing systems. The project envisions a new era of responsive manufacturing ecosystems, where production networks can adjust in real time to disruptions, ensuring both efficiency and productivity under challenging conditions.

## Objectives

Flex4Res is building an open platform based on the Gaia-X framework and the International Data Space Reference Architecture Model (IDS-RAM), enhanced with Asset Administration Shell (AAS) technology. Central to this platform are two toolboxes: one for resilience assessment and another dedicated to computing reconfiguration strategies. These toolboxes empower manufacturers to adapt swiftly and efficiently to disruptions, ensuring operational continuity and robustness across production networks. By leveraging advanced technologies, Flex4Res establishes a secure industrial data space using Gaia-X and International Data Spaces (IDS). This facilitates the seamless sharing and integration of Digital Twin models, enhancing predictive analysis and proactive decision-making. Supported by knowledge-based smart tools, this platform promotes collaboration and data interoperability, empowering stakeholders to share insights and best practices while maintaining data sovereignty.

| | |
|---|---|
| **Project Website** | www.flex4res.eu |
| in | Flex4Res-project |
| X | Flex4Res |
| **EFFRA portal** | https://portal.effra.eu/project/15691 |
| **YouTube** | @flex4res |

| | |
|---|---|
| **Call** | HORIZON-CL4-2022-TWIN-TRANSITION-01 |
| **Type of action** | HORIZON Innovation Actions |
| **Project duration** | 36 months, starting on 01.01.2023 |
| **Funding volume** | € 8 million |
| **Project volume** | € 10 million |
| **DG/Agency** | HADEA |
| **Coordinator** | LMS |

This initiative aims to strengthen the resilience of the European manufacturing industry by providing the capabilities needed for quick reconfiguration and adaptation to evolving challenges. By enhancing sustainability, competitiveness and responsiveness across the entire value chain, Flex4Res empowers manufacturing ecosystems to build flexible, resilient production frameworks that anticipate disruptions, mitigate risks and ensure long-term viability in an increasingly dynamic global market.

## Flex4Res approach

Flex4Res was inspired by recent global challenges, particularly the COVID-19 pandemic, which emphasised the vulnerabilities of global supply chains and their impact on production continuity. Manufacturing processes often depend on specialised skills and precise coordination, making them vulnerable to inefficiencies and delays when facing sudden demand shifts, the introduction of new products or external crises. The current landscape requires more than traditional lean manufacturing practices; it requires real-time adaptability and robust decision-making to withstand unexpected challenges and respond to dynamic market conditions.

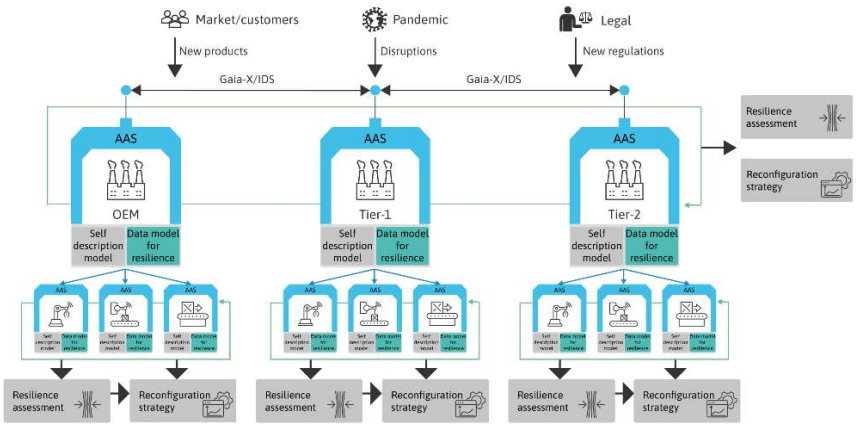


*Figure 1: Flex4Res approach*

To address this need, Flex4Res is developing an open, integrated platform that enables the seamless reconfiguration of production networks. By fostering trusted data exchange among stakeholders and enhancing interoperability, the platform improves coordination across the supply chain. To exchange data among stakeholders, the data space concept is utilised, and in detail the international data space (IDS) and Gaia-X data space (implementing the Pontus-X ecosystem). Central to this approach is the integration of Digital Twin technology, which provides real-time monitoring and insights for proactive decision-making. The DT are implemented using the Asset Administration Sell technology. The platform includes a resilience assessment toolbox that helps manufacturers identify vulnerabilities and plan robust contingencies, as well as a reconfiguration strategies toolbox to facilitate rapid adaptation during disruptions. Through these comprehensive solutions, Flex4Res

envisions a manufacturing sector that is not only resilient but also highly collaborative, sustainable, and capable of maintaining productivity under diverse conditions.

## Project pilot cases

The integrated solutions developed in Flex4Res are tested and validated through four industrial use cases, focusing on different types of manufacturing systems across various hierarchical layers: macro, meso and micro level. Figure 2 presents the four use cases, and in which hierarchical level each use case fits. In a further analysis, the macro level refers to the supply chain and network level, which involves broader coordination across different organisations or plants. The meso level refers to the production system and production lines, focusing on the coordination within a specific factory or production site. Finally, the Micro level refers to machines and devices, concentrating on the individual equipment or components within a production line.

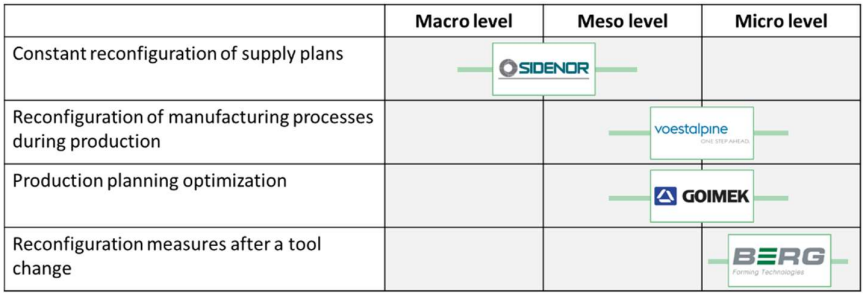


*Figure 2: Flex4Res use cases*

1. Reconfiguration measures after a tool change with Hans Berg: The use case focuses on minimising reconfiguration time after tool changes, reducing defective components, and lessening reliance on employee experience for adjustment tasks, enhancing efficiency and quality.
2. Production planning optimisation with GOIMEK: The use case develops a cross-site production planner to optimise process steps, boosting efficiency, competitiveness, and production predictability by enabling constant reconfiguration based on daily needs.
3. Reconfiguration of manufacturing processes during production: The voestalpine use case aims to enable flexible production planning and scheduling, adapting to product variations, machine state, and tools, allowing process reconfiguration during production for optimised efficiency.
4. Constant reconfiguration of supply plans with Sidenor Group: The use case aims to reduce reconfiguration time for production plans, enhancing coordination between network-level decisions and factory-level adjustments, and supporting users in reconfiguration planning amid disruptions.

## Achievement so far

Flex4Res has made significant progress toward its objectives. The project has successfully developed an initial version of its open platform integrating the Gaia-X

framework, IDS Reference Architecture Model, and Asset Administration Shell (AAS) technology. Regarding the Asset Administration Shell Models, the Industrial Digital Twin Association (IDTA) were utilised, but also new submodels have been designed and deployed. Moreover, two toolboxes have been developed. Firstly, the resilience assessment toolbox, which enables manufacturers to evaluate their production systems' ability to withstand disruptions, based on different methodologies, i.e., Penalty of change, value stream method, Bayesian networks etc. Secondly, a reconfiguration strategies toolbox has been designed, providing essential tools to support adaptive responses to changes in production conditions. Early demonstrations have highlighted the platform's capacity to facilitate efficient data sharing across the industrial data space, supporting the exchange of AAS models. Through these efforts, Flex4Res is laying the groundwork for smarter, more agile manufacturing processes, strengthening the resilience of European production networks and improving collaboration across the supply chain. The platform's advancements underline its potential in enhancing real-time decision-making and promoting innovative reconfiguration strategies.

## Looking ahead

Flex4Res project will deliver transformative outcomes that will shape the future of resilient manufacturing. One of the key expected outcomes is the establishment of a federated data space framework, which will ensure secure and sovereign data exchange across the entire supply chain, enabling stakeholders to collaborate effectively while overcoming interoperability barriers. Another expected outcome of the project is the resilience assessment toolbox, offering manufacturers the ability to assess vulnerabilities in real-time and implement data-driven strategies to minimise risks and enhance adaptability. Additionally, Flex4Res aims to provide inefficiency monitoring and auto-diagnostic cycles for maintenance flexibility. By utilising advanced monitoring tools, the project will enable manufacturers to detect inefficiencies early and adapt maintenance practices dynamically, reducing downtime and optimising production. A resilient production planner, based on real-time monitoring of machine status and production execution, will also be developed to enhance planning accuracy and flexibility, ensuring that disruptions are addressed proactively. Finally, the project will focus on the optimised reconfiguration of value chains, enabling manufacturing networks to adjust quickly and cost-effectively in response to changing market conditions, supply chain disruptions, and other external challenges.

## Conclusion and future steps

In conclusion, the Flex4Res project has made significant improvement in enhancing the resilience and flexibility of manufacturing systems through its innovative platform and toolboxes. By addressing key challenges such as reconfiguration of production processes, supply chain disruptions and the integration of digital twins by implementing AAS, the project Flex4Res has established the groundwork for more adaptive, responsive manufacturing ecosystems. Looking ahead, Flex4Res will continue to refine its toolboxes for resilience assessment and reconfiguration strategy computation, ensuring that the European manufacturing industry can not only recover quickly from disruptions but also thrive in the face of future uncertainties. Future steps will include scaling the platform's capabilities across more industries, further integrating AI and data analytics tools, and strengthening cross-sector collaboration to drive continuous improvement in resilience management.

## Coordinator contact:

Dr. Kosmas Alexopoulos
E-mail: alexokos@lms.mech.upatras.gr
Laboratory for Manufacturing Systems & Automation (LMS)

**Flex4Res partners:**



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101091903.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.