# D3.1 Gap analysis and opportunities recommendations 08/2025

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**RISE-SME:** Resilient Industry Supply Chain Enhancement for SMEs

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# Executive summary

This deliverable lays the foundation for a resilient, interconnected, and inclusive industrial landscape, ensuring that digital innovation benefits all SMEs, regardless of their technological maturity.

The document shows a cross-comparison of advanced technologies and their applications across different ecosystems, assessing their maturity and potential impact. The analysis spans four key ecosystems—digital (Mobility-as-a-Service), agrifood (wine industry), textile (shoe and apparel), and automotive (electric vehicles). Technologies under consideration include Artificial Intelligence, Digital Twin, Internet of Things (IoT), Blockchain, Data Space, 5G Connectivity, Edge Computing, AR/VR, Robotics and 3D Printing.

Using a structured three-step methodology—desk research, stakeholders survey, and gap analysis—the document assesses how the selected technologies are applied, their relevance, and their contribution to ecosystem resilience.

The analysis highlights both common and ecosystem-specific gaps in the adoption of digital technologies across industrial sectors. Common challenges identified across all ecosystems include the underutilization of resilience capabilities such as financial strength, limited deployment of redundancy across supply chains, and fragmented use of complementary technologies like AI, robotics, and edge computing. Additionally, SMEs across ecosystems face similar barriers to digital adoption, notably high costs, technological complexity, and a lack of digital skills.

Beyond these shared issues, specific gaps were observed within individual ecosystems. For example, the agrifood sector struggles with connectivity limitations in rural areas, which hinder real-time data sharing. In the automotive ecosystem, innovation is constrained by OEM-driven adoption models, which slow down SME integration.

To address these challenges, the report proposes a set of cross-cutting recommendations, including the integration of multiple technologies, the development of modular and affordable solutions for SMEs, and the promotion of collaborative innovation frameworks, training programs, and digital literacy initiatives. Additionally, ecosystem-specific recommendations—such as designing innovation roadmaps aligned with resilience goals and strengthening Digital Innovation Hubs—are suggested, with potential for adaptation and implementation across other sectors. These measures aim to foster a more inclusive and resilient digital transformation across all industrial ecosystems.

The final output of this analysis is a heatmap of technological gaps, application areas, and adoption potential, leading to the development of a matchmaking tool that will connect technology providers with SMEs in need, promoting cross-ecosystem collaboration and accelerating digital transformation.

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# 1 Introduction

The implementation of digital technologies in industrial ecosystems is not uniform. While some sectors have embraced digital technologies to great extend, other remain low digitalized, constrained by limitations of the proper ecosystem or uncertainty. This task sets out to explore this uneven landscape. It aims to identify the technological gaps between tech-savvy and traditional SMES, and to uncover opportunities for collaboration, transfer and an equal digital transformation of all ecosystems.

This deliverable compiles the results of a comprehensive analysis conducted across four key ecosystems: digital (Mobility-as-a-Service application), agrifood (wine industry), textile (shoe and apparel), and automotive (electric vehicles). The approach combines an exhaustive analysis of previous results from other project deliverables and a stakeholder survey to assess the maturity and impact of ten digital technologies. Each technology was evaluated in the context of the industrial ecosystems in terms of applications, relevance and contribution to resilience according to the characteristics of the sectors and specific challenges.

The methodology followed a layered framework. first, a mapping exercise identified where the digital technologies are currently applied and to what extent. Secondly, an online survey collected insights from clusters, Digital Innovation Hubs (DIHs), and SMEs, capturing perceptions of maturity, barriers, and needs. Finally, a gap analysis compared the resilience capabilities provided by the digital technologies with the critical factors affecting each ecosystem. This 3-step approach enabled a clear understanding of both technological potential and practical limitations.

This analysis presents the different realities of digital transformation in four relevant ecosystems. Some technologies, such as AI and 5G, demonstrate a high level of maturity in the digital ecosystem, illustrated with real-time applications and infrastructure readiness. Others, like blockchain or AR/VR, remain underutilized despite their strategic potential. In more traditional ecosystems, such as agrifood and textile, technologies are being implemented gradually in a strategic approach, for example improving operations, rather than driving transformation.

This seeks to understand how digital technologies interact with the ecosystems they are implemented in, how they contribute to resilience, and what prevents their broader adoption. The findings will guide the development of a matchmaking tool designed to bridge the gap between technology providers and SMEs, fostering cross-ecosystem collaboration and accelerating digital transformation in traditional SMEs.

In summary, Task 3.1 establishes the foundation for a more interconnected, resilient, and inclusive industrial landscape, one where digital innovation is not reserved for tech-savvy SMEs but also for traditional SMEs in all the ecosystems.

## 1.1 Purpose and scope

The objective of this deliverable is to identify and analyse the digital technological gap that exists between traditional and tech-savvy SMEs across four industrial ecosystems: digital, agrifood, textile and automotive. These gaps reflect deep differences between characteristics, infrastructures, processes, skills, investment capacity and digitalization readiness. Understanding this is essential to foster fruitful collaboration, and enable technology transfer and digital take up.

T3.1 seeks to establish a foundation for a matchmaking tool that links SMEs with appropriate technology providers. The scope of the task involves mapping the digital technologies' maturity and impact, evaluating their contributions to resilience, and identifying the barriers that prevent their wider adoption. For this, ten digital technologies have been analysed, artificial intelligence (AI), robotics, Internet of Things (IoT), blockchain, edge computing, augmented reality/virtual reality (AV/VR), digital twins (DT), 3D printing, data spaces and 5G connectivity.

The deliverable focuses on comparing the application of these technologies across ecosystems, highlighting areas of significant advancement and those that remain underutilized. It further explores the conditions that facilitate or hinder their deployment. Ultimately, the scope of this work is to provide actionable insights that assist SMEs in navigating digital transformation, and to establish a foundation for cross-sector synergies that enhance industrial resilience.

## 1.2 Methodology

**Activity 1: Desk research analysis**

For the technology maturity analysis included in Section 2 of this deliverable, a Mapping of Advanced Technologies by Ecosystems was carried out.
The assessment is based on the desk research conducted in D2.2 and its findings, including technology applications, supplier mapping, resilience capabilities, barriers to adoption and the specific challenges faced by each ecosystem.
These findings were analysed by technology, evaluating its relevance to each ecosystem, current deployment status, and capability to address resilience challenges.
To assess the maturity and the impact levels of each technology, a three-level system was defined as follows:

*Table 1: Technology Maturity Levels*

| Level | Definition |
|---|---|
| **Low** | Technology is in early-stage development or pilot phase; limited adoption. |
| **Medium** | Technology is proven in some sectors but not yet widely adopted in the ecosystem. |
| **High** | Technology is mature, widely adopted, and has demonstrated impact in the ecosystem. |

*Table 2: Technology Impact Levels*

| Level | Definition |
|---|---|
| **Niche** | Limited to specific use cases or experimental applications. |
| **Strategic** | Enables key functions or improvements in resilience and operations. |
| **Transformative** | Fundamentally changes how the ecosystem operates, enabling new business models. |

**Activity 2: Online survey**

The desk research analysis was complemented with the launch of a survey to the clusters and DIHs involved in the consortium. The idea was to compare the actual state of the art with the perceived maturity of technologies applications in the different ecosystems.

The survey was designed around the technologies identified in deliverable 2.2, with specific questions on gaps and barriers, as well as on the supplier landscape.

**Activity 3: Gap analysis**

The gap analysis and the recommendations included in Sections 4 and 5 of this deliverable were assessed by comparing the findings of different analyses conducted throughout the project.
The critical factors identified for each ecosystem in D1.1 were compared with those addressed by the digital technology applications identified in D2.2, in order to understand how the existing digital applications work towards the critical challenges within each ecosystem.
The resilience capabilities provided by the digital technologies applied to each sector (identified in D2.2) were compared with the resilience capabilities required to address each critical factor in the sector (identified in D1.2).
The combination of these analyses allowed the identification of:

- Gaps in critical factors that are not currently addressed by digital technologies.
- Gaps in resilience capabilities that are not being utilized to enhance the resilience of the sector.

**Activity 4: Matchmaking tool design**

Last, the structure of a matchmaking tool for users and providers of technologies has been created. The tool will be populated during the life of the project, capitalizing the results of work package 3.

## 1.3 Structure of the deliverable

This deliverable is organised into six main sections, each contributing to the overall objective of identifying technological gaps and opportunities for resilience across industrial ecosystems.

Section 1: Introduction

- Introduction, purpose, scope, and methodology of the analysis. It outlines the rationale behind Task 3.1 and explains how the findings were gathered and validated.

Section 2: Technology maturity

- Technology maturity analysis, structured by ecosystem. It includes detailed mappings of advanced technologies in the ecosystems. Each technology is assessed in terms of maturity, impact, key applications, resilience capabilities, and adoption barriers.

Section 3: Matchmaking tool

- Description of the the matchmaking tool being developed to connect traditional and tech-savvy SMEs. It outlines the tool's structure, functionality, and intended use as a practical resource for collaboration and technology transfer

Section 4: Gap analysis

- Gap analysis, comparing the resilience needs of each ecosystem with the capabilities offered by current digital technologies. This section identifies where technologies are underutilized or misaligned with sector-specific challenges

Section 5: Recomendations and outlook

- Recommendations and outlook, offering strategic guidance on how to address the identified gaps. It includes suggestions for technology deployment, ecosystem-specific priorities, and policy support measures.

Together, these sections present a comprehensive overview of the current state of digital technology adoption in industrial ecosystems and lay the groundwork for future collaboration and innovation.

# 2 Technology maturity

## 2.1 Mapping of Advanced Technologies by Ecosystems

The mapping of the advanced technologies per ecosystem analyzes the main results and findings from D2.2 for the 10 most relevant digital technologies:

- Artificial Intelligence
- Digital Twin
- Internet of Things (IoT)
- Blockchain
- Data Space
- 5G Connectivity
- Edge Computing
- AR/VR
- Robotics
- 3D Printing

### 2.1.1 Digital Ecosystem – MaaS application

The digital ecosystem, with a focus on Mobility-as-a-Service (MaaS), is undergoing rapid transformation driven by the integration of advanced digital technologies. These technologies are essential for enhancing resilience, adaptability, and efficiency in urban mobility systems. This assessment identifies the maturity, application areas, resilience contributions, and adoption barriers of ten key technologies in the MaaS context, based solely on the findings from Deliverable D2.2.

#### 2.1.1.1 Artificial Intelligence (AI) in digital

**Maturity Level: High**

- AI is already widely deployed in MaaS platforms for route optimization, demand prediction, and autonomous mobility services. It is considered a mature technology in this domain.

**Impact Level: Transformative**

- AI enables real-time, adaptive, and predictive capabilities that fundamentally change how mobility services are delivered, integrated, and optimized.

**Applications in digital**

AI is central to the operation and evolution of MaaS platforms. According to D2.2, key applications include:

- **On-demand mobility orchestration**: AI powers dynamic ride-pooling and vehicle dispatching systems (e.g., ioki).
- **Autonomous vehicle integration**: AI enables perception, decision-making, and control systems for self-driving vehicles.

- **Intermodal route planning**: AI algorithms optimize travel across multiple transport modes (e.g., Siemens Mobility).
- **User behavior prediction**: AI analyzes historical and contextual data to anticipate user preferences and travel patterns.
- **Incident response and rerouting**: AI supports real-time decision-making in response to traffic disruptions or service outages.
- **Demand and weather prediction**: AI advanced forecasting models can predict weather or demand to adjust the service characteristics and requirements accordingly.

These applications are aligned with the resilience needs identified in the MaaS sector such as:

- Constant changes in service offerings and traffic conditions
- User identification and payment reliability
- Regulatory compliance and data privacy
- Onboarding and loyalty of new users

**Resilience Capabilities**

AI contributes to several resilience dimensions:

*Table 3: Resilience Capabilities of AI in MaaS.*

| Capability | Description |
|---|---|
| Adaptability | AI enables systems to learn from data and adjust to changing conditions. |
| Efficiency | Optimizes resource allocation, vehicle routing, and energy consumption. |
| Visibility | Provides real-time insights into system performance and user behavior. |
| Responsiveness | Supports rapid decision-making in dynamic environments. |

Examples found in D2.2:

- **ioki**: Offers AI-powered ride-pooling and demand-responsive transport.
- **Siemens Mobility**: Integrates AI into MaaS platforms for intermodal planning and infrastructure resilience.

**Adoption Barriers**

Despite its maturity, AI adoption in MaaS faces several challenges:

*Table 4: Adoption Barriers for AI in Maas.*

| Barrier | Explanation |
|---|---|
| System interoperability | Integrating AI with legacy transport systems can be complex. |
| Data privacy concerns | AI requires access to sensitive user and operational data. |

| | |
|---|---|
| **Public acceptance** | Especially relevant for AI-driven autonomous services. |
| **High implementation costs** | Developing and maintaining AI systems requires significant investment. |
| **Need for skilled personnel** | AI deployment depends on data scientists and engineers. |

These barriers are consistent with those identified across ecosystems.

In conclusion, Artificial Intelligence is a **mature and transformative** technology in the MaaS ecosystem. It directly addresses key resilience challenges by enabling real-time and adaptive service delivery, predictive maintenance and demand forecasting, and seamless integration of multimodal transport. However, its full potential is contingent on overcoming barriers related to interoperability, data governance, and public trust.

#### 2.1.1.2 Digital Twin in digital

**Maturity Level: High**

- Digital Twin technology is well-established in urban mobility planning and infrastructure simulation, with multiple commercial solutions deployed in European cities.

**Impact Level: Strategic to Transformative**

- Digital Twins enable predictive, data-driven decision-making and infrastructure optimization, which are essential for resilient and adaptive MaaS systems.

**Applications in MaaS**

Digital Twins are used in MaaS to:

- **Simulate traffic flow and congestion**: Tools like Aimsun and PTV Group model multimodal transport networks to optimize road design and reduce emissions.
- **Evaluate infrastructure performance**: Real-time data integration allows for scenario testing, infrastructure stress analysis and contingency plans.
- **Support intermodal planning /multimodal coordination**: Digital Twins help coordinate buses, trains, micromobility, and ride-sharing services by a unified simulation.
- **Enable "what-if" simulations**: Cities can test the impact of new policies, disruptions, or service changes before implementation.
- **Visualize urban mobility systems**: virtual replicas of the urban transport network improve stakeholder communication and planning.

These applications directly address the resilience challenges identified in Maas, such as:

- Constant changes in service offerings and traffic conditions
- Infrastructure and technological disruptions
- Regulatory compliance and planning complexity

**Resilience Capabilities**

*Table 5: Resilience Capabilities for digital twins in Maas.*

| Capability | Description |
|---|---|
| Adaptability | Simulates and tests new configurations before deployment. |
| Efficiency | Optimizes traffic flow, resource allocation, and infrastructure use. |
| Visibility | Provides real-time and predictive insights into system performance. |

Examples found in D2.2:

- **AnyLogic**: uses digital twins for traffic simulation and logistics modeling.
- **Aimsun**: offers a multimodal urban mobility modeling using digital twins.
- **PTV Group**: integrates transport infrastructure planning and optimization through digital twins.

**Adoption Barriers**

*Table 6: Adoption Barriers for digital twins in Maas.*

| Barrier | Explanation |
|---|---|
| Standardization challenges | Lack of common data formats and APIs across transport operators. |
| Training needs | Requires skilled personnel to build, calibrate, and interpret simulations. |
| Integration with legacy systems | Older infrastructure may not support real-time data feeds. |

In conclusions, Digital Twin is a **mature and strategically transformative technology** in the MaaS ecosystem. It supports predictive planning, infrastructure optimization, and real-time coordination across transport modes. By enabling scenario testing and system visualization, it enhances adaptability and visibility. However, its broader adoption depends on overcoming challenges related to standardization, integration with legacy systems, and the need for specialized training.

#### 2.1.1.3 Block chain in digital

**Maturity Level: Medium to High**

- Blockchain is increasingly adopted in MaaS for secure data exchange, decentralized identity, and automated transactions, though full-scale deployment is still emerging.

**Impact Level: Strategic**

- Blockchain enhances trust, transparency, and automation in MaaS ecosystems, especially where multiple operators and regulatory bodies interact.

**Applications in MaaS**

Blockchain is used in MaaS to:

- **Enable decentralized identity and authentication**: Riders can use a single digital identity across multiple transport providers.
- **Secure data exchange and traceability**: Immutable ledgers ensure the integrity of trip data, payments, and regulatory attestations.
- **Automate fare settlement**: Smart contracts execute payments instantly upon trip completion, reducing disputes and delays.
- **Support decentralized mobility marketplaces**: Blockchain enables peer-to-peer services like ride-sharing, parking, and vehicle rentals.
- **Enhance compliance and auditing**: Blockchain logs can be used for transparent reporting to regulators.

These applications address key resilience challenges in MaaS, including:

- Data privacy and user trust
- Interoperability between operators
- Payment reliability and liquidity
- Regulatory compliance and auditability

**Resilience Capabilities**

*Table 7: Resilience Capabilities for blockchain in Maas.*

| Capability | Description |
|---|---|
| Visibility | Immutable records of transactions and service events. |
| Respond | Enables automated response to disruptions via smart contracts. |
| Efficiency | Automated processes reduce administrative overhead. |
| Market strength | Builds trust and transparency across decentralized mobility markets. |
| Transform | Facilitates new business models through peer-to-peer mobility services. |
| Financial strength | Reduces transaction costs and improves liquidity through instant settlements. |
| Security | Cryptographic protocols ensure data integrity and access control. |
| Adaptability | Supports flexible, decentralized service models. |

Examples found in D2.2:

- **Transchain**: Provides immutable B2B traceability and data exchange using blockchain technologies.
- **IoMob**: Enables a decentralized mobility marketplace and integrated payment systems.
- **Nextrope**: Develops peer-to-peer smart parking solutions and DLT-based applications.

- **FISTA Solutions**: Implements smart contracts for decentralized ride-sharing platforms.

**Adoption Barriers**

*Table 8: Adoption Barriers for blockchain in Maas.*

| Barrier | Explanation |
|---|---|
| **Interoperability issues** | Different blockchain platforms may not communicate easily. |
| **Regulatory uncertainty** | Legal frameworks for smart contracts and decentralized identity are evolving. |
| **High investment costs** | Initial setup and integration with legacy systems can be expensive. |
| **Digital literacy gaps** | Integration complexity with legacy infrastructure. Users and operators may lack familiarity with blockchain-based systems. |
| **Lack of industry standards** | Fragmented protocols hinder interoperability. |
| **Data privacy concerns** | Immutable ledgers may conflict with GDPR requirements. |
| **IT/OT limited integration** | Operational systems may not support blockchain interfaces. |
| **Customization complexity** | Tailoring blockchain solutions to specific MaaS needs is resource-intensive. |
| **User adoption reluctance** | Users may be hesitant to trust decentralized systems. |

In conclusion, Blockchain is a **strategic and increasingly mature technology** in MaaS. It strengthens trust, transparency, and automation through decentralized identity, secure data exchange, and smart contracts. Its resilience contributions include auditability, financial efficiency, and adaptability. Yet, adoption is slowed by regulatory uncertainty, interoperability issues, and the complexity of integrating blockchain into existing systems.

#### 2.1.1.4 Data Spaces in digital

**Maturity Level: Medium**

- Data Spaces are emerging as a key enabler of secure, interoperable data exchange in MaaS, especially through EU-led initiatives like Gaia-X and iShare.

**Impact Level: Strategic**

- Data Spaces provide the foundation for cross-operator collaboration, real-time data sharing, and regulatory compliance in decentralized MaaS ecosystems.

**Applications in MaaS**

Data Spaces are used in MaaS to:

- **Enable secure, federated data sharing**: Operators retain control over their data while sharing it through standardized APIs.

- **Support real-time service coordination**: Data Spaces allow public and private transport providers to exchange availability, capacity, and status information.
- **Facilitate identity and access management**: Platforms like iShare provide trusted frameworks for authentication and authorization.
- **Ensure data sovereignty**: Participants define usage policies and access rights, aligning with GDPR and other regulations.
- **Interoperability for MaaS actors**: Data Spaces allow seamless orchestration of buses, trains, scooters, and ride-hailing services.

These applications address key MaaS challenges such as:
- Fragmented data silos
- Lack of interoperability
- Regulatory compliance
- Real-time service integration

**Resilience Capabilities**

*Table 9: Resilience Capabilities of Data Spaces in Maas.*

| Capability | Description |
|---|---|
| **Visibility** | Real-time access to distributed datasets across operators. |
| **Adaptability** | Supports dynamic integration of new services and partners. |
| **Efficiency** | Reduces duplication and manual data reconciliation. |

Examples found in D2.2:
- **Gaia-X**: Provides federated data infrastructure for MaaS and broader digital ecosystems.
- **TNO**: Develops open mobility data ecosystems and standards to support interoperability.
- **iShare (INNOPAY)**: Offers identity and access management solutions for logistics and MaaS platforms.

**Adoption Barriers**

*Table 10: Adoption Barriers for Data Spaces in Maas.*

| Barrier | Explanation |
|---|---|
| **Governance complexity** | Requires agreement on data models, access rules, and trust frameworks. |
| **Standard adoption lag** | Not all actors are ready to implement common protocols (e.g., IDS, DCAT). |
| **Legacy system integration** | Older IT systems may not support real-time API-based data exchange. |
| **Awareness and training** | Many stakeholders are unfamiliar with the concept and benefits of Data Spaces. |

In conclusion, Data Spaces are an **emerging and strategic** enabler of interoperability and secure data sharing in MaaS. They facilitate real-time coordination, data sovereignty, and compliance with EU regulations. Their resilience value lies in visibility, adaptability, and efficiency. Still, widespread implementation is challenged by governance complexity, uneven standard adoption, and limited awareness among stakeholders.

### 2.1.1.5 5G Connectivity in digital

**Maturity Level: High**

- 5G is being actively deployed in urban mobility systems, enabling ultra-fast, low-latency communication essential for real-time MaaS operations.

**Impact Level: Transformative**

- 5G underpins the responsiveness, scalability, and security of MaaS platforms, enabling next-generation services such as autonomous mobility, real-time analytics, and seamless multimodal integration.

**Applications in MaaS**

5G Connectivity in MaaS enables:

- **Real-time communication between vehicles and infrastructure (V2X)**: Supports autonomous driving, traffic signal coordination, and hazard alerts.
- **High-speed data exchange**: Facilitates rapid transmission of telemetry, video feeds, and sensor data from vehicles and stations.
- **Network slicing**: Allocates dedicated bandwidth for critical services (e.g., emergency transport, autonomous fleets).
- **Edge computing integration**: Enables local processing of data for ultra-low latency applications.
- **Secure, high-throughput mobile connectivity**: Ensures uninterrupted service for users and operators, even in dense urban environments.

These applications address key MaaS challenges such as:

- Infrastructure disruptions
- Service continuity under peak loads
- Cybersecurity and data integrity
- Integration of autonomous and connected mobility

**Resilience Capabilities**

*Table 11: Resilience capabilities of 5G in Maas.*

| Capability | Description |
|---|---|
| Efficiency | Supports high-speed, low-latency communication for real-time operations. |
| Redundancy | Enables fallback and load-balancing across network slices. |
| Security & Stability | Provides encrypted, reliable communication channels. |

| | |
|---|---|
| **Market Strength** | Facilitates instant reaction to dynamic traffic and service conditions. |

Examples found in D2.2:

- **Nokia**: Applies network slicing and ultra-low latency transport for advanced mobility use cases.
- **Cellnex**: Facilitates infrastructure sharing to support 5G mobility applications.
- **BICS**: Provides secure connectivity solutions for MaaS providers.
- **Telit Cinterion**: Supplies 5G modules for digital transport platforms and IoT integration.

**Adoption Barriers**

*Table 12: Adoption barriers for 5G in Maas.*

| Barrier | Explanation |
|---|---|
| **High infrastructure costs** | 5G deployment requires dense antenna networks and significant investment. |
| **Regulatory dependencies** | Spectrum allocation and cross-border harmonization are complex. |
| **Cybersecurity risks & Geopolitical risks** | Increased connectivity expands the attack surface for malicious actors. Concerns over data privacy and cross-border connectivity agreements |
| **Integration with legacy systems** | Older transport infrastructure may not support 5G natively. |

In conclusion, 5G Connectivity is a **mature and transformative infrastructure** for MaaS. It enables ultra-fast, low-latency communication essential for real-time operations, autonomous mobility, and edge computing. Its resilience strengths include efficiency, redundancy, and secure service continuity. However, deployment is constrained by high infrastructure costs, regulatory dependencies, and cybersecurity risks.

#### 2.1.1.6 Edge Computing in digital

**Maturity Level: Medium to High**

- Edge computing is increasingly integrated into MaaS platforms, especially in conjunction with 5G and IoT, though adoption varies by region and infrastructure readiness.

**Impact Level: Strategic**

- Edge computing enables ultra-fast, localized data processing, which is critical for real-time decision-making, autonomous mobility, and resilient service delivery in MaaS.

**Applications in MaaS**

Edge Computing is used in MaaS to:

- **Process data locally at the network edge**: Reduces latency by avoiding round-trips to centralized cloud servers.
- **Enable real-time analytics and control**: Supports immediate responses to traffic changes, vehicle telemetry, and user behavior.
- **Support autonomous and connected vehicles**: Edge nodes process sensor data for navigation, safety, and coordination.
- **Enhance real-time multimodal service delivery**: Edge platforms integrate data from buses, scooters, trains, and ride-hailing in real time.
- **Improve resilience in low-connectivity environments**: Ensures continuity of operations even when cloud access is disrupted.

These applications address key MaaS challenges such as:

- Real-time responsiveness
- Infrastructure disruptions
- Data overload and bandwidth constraints
- Service continuity in disconnected scenarios

**Resilience Capabilities**

*Table 13: Resilience Capabilities of Edge Computing in Maas.*

| Capability | Description |
|---|---|
| **Efficiency** | Reduces bandwidth usage and cloud dependency. |
| **Visibility** | Enables real-time monitoring and analytics at the point of data generation. |
| **Adaptability** | Supports modular, scalable deployment across diverse transport nodes. |

Examples found in D2.2:

- **OnLogic**: Provides rugged edge computing hardware for transit systems and MaaS platforms.
- **T-Systems**: Develops edge-enabled platforms to support multimodal transport operations.

**Adoption Barriers**

*Table 14: Adoption barriers for Edge Computing in Maas.*

| Barrier | Explanation |
|---|---|
| **Integration complexity** | Requires coordination with IoT, cloud, and legacy systems. |
| **Deployment and maintenance** | Edge nodes must be physically installed and maintained across locations. |

| | |
|---|---|
| **Interoperability issues** | Diverse hardware and software stacks may hinder seamless integration. |
| **Customization needs** | Edge solutions often require tailoring to specific operational contexts. |

In conclusion, Edge Computing is a **strategic and increasingly adopted technology** in MaaS. It empowers real-time analytics, local decision-making, and service continuity in low-connectivity environments. Its resilience contributions include adaptability, efficiency, and visibility. Adoption barriers include deployment complexity, hardware requirements, and integration with cloud and legacy systems.

#### 2.1.1.7 AR/VR in digital

**Maturity Level: Medium**

- AR/VR technologies are increasingly used in MaaS for user interaction, navigation, and immersive experiences, though adoption is still growing and varies by region and operator.

**Impact Level: Strategic**

- AR/VR enhances user engagement, accessibility, and operational training, contributing to more intuitive, resilient, and user-centric mobility systems.

**Applications in MaaS**

AR/VR is used in MaaS to:

- **Enhance user navigation and orientation**: AR overlays guide users through complex transit environments (e.g., stations, multimodal hubs).
- **Improve in-vehicle experiences**: AR head-up displays (HUDs) provide real-time route, safety, and infotainment data.
- **Support immersive training**: VR simulations help train drivers, operators, and maintenance staff in safe, controlled environments.
- **Enable interactive public transport apps**: AR apps help users locate stops, plan routes, and receive contextual information.
- **Boost customer engagement**: Gamified AR experiences increase loyalty and satisfaction, especially in shared mobility services.

These applications address MaaS challenges such as:

- User onboarding and retention
- Accessibility and wayfinding
- Training and workforce development
- Service personalization and differentiation

### Resilience Capabilities

*Table 15: Resilience capabilities for AR/VR in Maas.*

| Capability | Description |
|---|---|
| Adaptability | Enhances user experience in dynamic environments. |
| Visibility | Provides real-time, context-aware information overlays. |
| Efficiency | Reduces training time and improves operational accuracy. |
| Market Strength | Increases user satisfaction and brand differentiation. |
| Transform | Enables immersive, personalized mobility experiences that redefine user interaction. |

Examples found in D2.2:

- **Moovit**: Offers AR-based transit navigation and station orientation for enhanced passenger experience.
- **WayRay**: Develops in-vehicle AR HUDs for navigation and infotainment systems.
- **arvision**: Provides AR applications for public transport guidance and user interaction.
- **Meta Reality Labs**: Creates immersive mobility AR experiences, including collaborations with automotive brands like BMW.

### Adoption Barriers

*Table 16: Adoption barriers for AR/VR in Maas.*

| Barrier | Explanation |
|---|---|
| Hardware costs | AR glasses and VR headsets remain expensive for large-scale deployment. |
| User adoption reluctance | Some users may find immersive tech unfamiliar or intrusive. |
| Integration complexity | AR/VR systems must interface with real-time data and legacy platforms. |
| Data privacy concerns | AR systems may collect sensitive location and behavioral data. |
| Regulatory challenges | Lack of clear guidelines for immersive tech in public transport. |
| Data privacy risks | AR systems may collect sensitive location and behavioral data. |

In conclusion, AR/VR is a **strategic and evolving technology** in MaaS. It enhances user experience, accessibility, and operational training through immersive and interactive applications. Its resilience impact includes improved adaptability, visibility, and user engagement. However, adoption is limited by hardware costs, user acceptance, and privacy concerns.

#### 2.1.1.8 Summary of digital maturity in digital

*Table 17: Digital maturity in digital.*

| Technology | Maturity | Impact | Key Applications | Resilience Capabilities | Adoption Barriers |
|---|---|---|---|---|---|
| **AI** | High | Transformative | On-demand mobility, route planning, autonomous vehicles, user behavior prediction | Adaptability, Efficiency, Visibility, Responsiveness | Integration complexity, data privacy, public acceptance |
| **Digital Twin** | High | Strategic | Mobility simulation, infrastructure planning, scenario testing | Adaptability, Efficiency, Visibility | Standardization, workforce training, legacy integration |
| **Blockchain** | Medium | Strategic | Decentralized identity, secure payments, smart contracts | Visibility, Efficiency, Security, Adaptability, Respond, Market strength, Transform, Financial strength | Interoperability, regulation, digital literacy, investment, industry standards, data privacy, integration, customization, complexity, user adoption reluctance |
| **Data Spaces** | Medium | Strategic | Federated data sharing, real-time coordination, data sovereignty | Visibility, Adaptability, Efficiency | Governance, standard adoption, integration, awareness |
| **5G Connectivity** | High | Transformative | V2X communication, real-time data exchange, network slicing | Efficiency, Redundancy, Security, Market strength | Infrastructure cost, regulation, cybersecurity, integration |
| **Edge Computing** | Medium | Strategic | Local data processing, real-time analytics, autonomous control | Efficiency, Visibility, Adaptability | Deployment complexity, integration, customization, interoperability |
| **AR/VR** | Medium | Strategic | AR navigation, immersive training, user engagement | Adaptability, Visibility, Efficiency, Market Strength, Transform | Hardware cost, user adoption, privacy, integration, regulation |

### 2.1.2 Agri-food Ecosystem: Wine sector

The agri-food ecosystem limits from agricultural production and fisheries to processing, packaging, distribution, and retail. It is critically exposed to environmental, logistical, and market disruptions. Advanced digital technologies such as AI, IoT, blockchain, 3D printing, and data spaces play a pivotal role in improving operational efficiency and enhancing supply chain resilience. This assessment evaluates the maturity, application areas, resilience contributions, and adoption barriers of these technologies in the agri-food sector, using supplier examples and insights from Deliverable D2.2.

#### 2.1.2.1 Artificial Intelligence (AI) in Agri-food

**Maturity Level: High**

- AI is increasingly adopted for forecasting and monitoring, especially in SMEs, but predictive maintenance integration is still developing.

**Impact Level: Strategic**

- AI strengthens supply-demand alignment and resource optimization but has yet to fully transform production models.

**Applications in wine sector**

AI supports:

- Demand Forecasting (Blue River, Prospera, CropX)
- Predictive Maintenance (CeresAI)
- Crop Monitoring and Real-time Decision Making
- Soil Data Analytics
- Proactive Resource Optimization

This helps mitigate:

- Volatile demand & climate variability
- Equipment failure risks
- Manual oversight inefficiencies

**Resilience Capabilities**

*Table 18: Resilience capabilities for AI in agrifood.*

| Capability | Description |
|---|---|
| Adaptability | Forecasts enable rapid response to environmental and market changes. |
| Efficiency | Optimized crop decisions, input use, and maintenance scheduling. |
| Flexibility | Real-time adaptation to soil and weather data. |

**Examples found in D2.2:**

- **Blue River Technology**: Offers AI-driven predictive analytics for crop demand forecasting and supply chain optimization.
- **Prospera Technologies**: Provides real-time crop monitoring AI and soil data analytics to enhance forecasting and farm decision-making.

- **CropX**: Delivers AI-based tools for demand forecasting and real-time agronomic insights through soil sensors.
- **CeresAI**: Specializes in predictive maintenance solutions using AI to reduce downtime and improve equipment efficiency in agricultural operations.

**Adoption Barriers**

*Table 19: Adoption barriers for AI in agrifood.*

| Barrier | Explanation |
|---|---|
| **Data infrastructure gaps** | Limited access to reliable broadband, data storage, and sensor networks in rural areas |
| **Skill shortages** | Lack of trained personnel to implement, interpret, and maintain AI tool |
| **High cost** | High costs for AI tool deployment |
| **Integration** | Integration with legacy machinery |

In conclusion, AI is a strategic and maturing technology in the agri-food (wine) sector. It supports precision farming, crop forecasting, and predictive maintenance, enhancing adaptability, efficiency, and flexibility across operations. Its adoption, however, is limited by infrastructure costs, data integration challenges, and skill shortages among agricultural workers.

### 2.1.2.2 Internet of Things (IoT) in Agri-food

**Maturity Level: Medium**

- Proven in use across farms but adoption depends on network and infrastructure availability.

**Impact Level: Strategic**

- Boost operational continuity and remote management in fragmented supply chains.

**Applications in wine sector**

IoT supports:

- Farm Climate & Irrigation Automation (SENSEFARM)
- Input Efficiency Dashboards (LIBELIUM)
- Logistics Visibility (Plantea)
- IoT + Blockchain for Traceability (Altim)

IoT addresses:

- Labor shortages
- Environmental monitoring
- Cold chain and logistics disruptions

### Resilience Capabilities

*Table 20: Resilience capabilities for IoT in agrifood.*

| Capability | Description |
|---|---|
| **Efficiency** | Automated input and climate systems reduce waste |
| **Visibility** | Real-time alerts across logistics and operations |
| **Respond** | Instant reaction to environmental or equipment events |

- **LIBELIUM**: Designs and manufactures IoT hardware and software for smart agriculture, enabling dashboard-linked automation and sensor-based monitoring of input efficiency.
- **SENSEFARM**:. Now a dedicated IoT firm, Sensefarm collaborates with local farmers and research institutions to develop fully automated farm climate and irrigation systems, boosting operational efficiency and adaptability.
- **Plantea**: Their platform provides data visualization and decision support tools, helping producers make precise and sustainable irrigation and cultivation choices.
- **Altim**: Combines IoT and blockchain to offer end-to-end traceability and real-time compliance monitoring. Their solutions help agri-food businesses meet regulatory demands while promoting environmentally responsible practices.

### Adoption Barriers

*Table 21: Adoption barriers for IoT in agrifood.*

| Barrier | Explanation |
|---|---|
| **Coonectivity** | Connectivity issues in rural areas |
| **Integration complexity** | Difficulty integrating IoT platforms with legacy systems and heterogeneous farm equipment |
| **Maintenance costs** | Ongoing costs for hardware upkeep, sensor calibration, and technical support |
| **Regulatory compliance** | High upfront CAPEX |

In conclusion, IoT is a strategic technology in the agri-food ecosystem, enhancing efficiency, visibility, and responsiveness through automation and real-time monitoring. Despite its benefits in areas like irrigation and logistics, its adoption is hindered by high upfront costs, rural connectivity issues, and integration complexity.

### 2.1.2.3 Blockchain in wine sector

**Maturity Level: Medium**

•Widespread pilots, but full supply chain integration is limited by interoperability.

**Impact Level: Strategic**

•Revolutionizes product transparency and ethical sourcing.

**Applications of blockchain**

Blockchain supports:

- End-to-End Product Traceability (OpenSC, ORIGIN CHAIN)
- Secure Smart Contracts & Micro-payments (Ianthu, AgriDigital)
- NFT Tokens for Farming Action-Proof (ORIGIN CHAIN)

Blockchain addresses:

- Compliance and certification
- Food safety and provenance
- Secure producer payments

**Resilience Capabilities**

*Table 22: Resilience capabilities for blockchain in agrifood.*

| Capability | Description |
|---|---|
| **Visibility** | Tracks full lifecycle of agri-goods |
| **Efficiency** | Reduces auditing time, simplifies compliance |
| **Adaptability** | Rapid reaction to safety issues and recalls |

Examples found in D2.2:

OpenSC: Uses real-time supply chain data to verify sustainability and ethical sourcing claims through blockchain, ensuring transparency and trust. Their platform continuously monitors supply chain activity to provide immutable records for environmental and social compliance.

AgriDigital: A comprehensive commodity management platform focused on global grain supply chains. AgriDigital integrates blockchain for supply chain traceability, digital title creation, inventory finance, and real-time payments.

Ianthu: Blockchain startup offering traceability solutions for food and agricultural supply chains. Though currently unfunded, LLanthu operates in a competitive environment with over 200 traceability technology providers and focuses on providing secure, blockchain-based transaction validation in emerging markets.

ORIGIN CHAIN Networks: Specializes in regenerative farming validation via blockchain and NFT minting, promoting traceability, adaptability, and transformation within food production systems.

**Adoption Barriers**

*Table 23: Adoption barriers for blockchain in agrifood.*

| Barrier | Explanation |
|---|---|
| **Literacy gaps** | Limited awareness and understanding of blockchain concepts among agri-food stakeholders |
| **Skill shortages** | Lack of technical expertise to develop, integrate, and maintain blockchain platforms |
| **Stakeholder resistance** | Reluctance from traditional actors to adopt decentralized and transparent systems |
| **Platform interoperability** | Offline sync and platform compatibility |
| **Regulatory alignment** | Unclear or evolving legal frameworks for blockchain usage and digital contracts |

In conclusion, Blockchain is a strategic and potentially transformative technology in agri-food. It strengthens resilience by enabling secure traceability, compliance, and payments, improving visibility and adaptability. Yet, its adoption is limited by interoperability barriers, regulatory uncertainty, and digital literacy gaps**.**

### 2.1.2.4 Data spaces in agrifood

**Maturity Level: Medium-Low**

- Still developing. Requires industry-wide standards and onboarding.

**Impact Level: Strategic**

- It has potential to unify fragmented agri-food quality systems

**Applications of data spaces**

Data spaces support:

- Real-Time Data Sharing (AgriDigital)
- Ingredient Management & Transparency (TraceGains)

Helps with:

- Collaborative safety assurance
- Audit-readiness
- Integrated compliance monitoring

**Resilience Capabilities**

*Table 24: Resilience capabilities for data spaces in agrifood.*

| Capability | Description |
|---|---|
| **Visibility** | Transparency across stakeholders |
| **Compliance** | Standardized, real-time data access |
| **Efficiency** | Streamlined certification & reporting |

TraceGains: Offers a cloud-based network for food supply chain transparency and compliance. Its platform supports ingredient-level data sharing, documentation management, and audit readiness, helping producers and processors align with evolving food safety standards.

AgriDigital: In addition to its blockchain applications, AgriDigital functions as a data-sharing platform that supports grain supply chain operations. It enables real-time visibility and digital recordkeeping across producers, traders, and buyers, enhancing operational coordination and infrastructure resilience.

**Adoption Barriers**

*Table 25: Adoption barriers for data spaces in agrifood.*

| Barrier | Explanation |
|---|---|
| **Complex onboarding** | Lengthy and resource-intensive process for connecting stakeholders to the data-sharing network |
| **Data standard alignment** | Lack of harmonized data formats and taxonomy across producers, suppliers, and regulatory bodies |
| **Connectivity dependencies** | Limited internet access in rural areas affecting real-time data syncing and sharing |

Data spaces have the potential to provide shared, trusted environments for quality control, certification, and compliance in the agri-food sector. While the strategic value is clear, the maturity level is still low, with adoption limited by onboarding complexity, lack of standardization, and uneven connectivity. Aligning stakeholders on common data models and developing easy-to-use collaborative dashboards would help increase adoption and unlock their benefits.

#### 2.1.2.5 3D Printing in agrifood

**Maturity Level: Medium-Low**

- Still in first stages of implementation. High cost and material constraints limit broader adoption.

**Impact Level: Stategic-Niche**

- High impact on specific repair and customization tasks.

**Applications of 3D printing in wine sector**

3D printing supports:

- Food-Safe Equipment Prototyping (Oceanz)
- Portable 3D Food Printers (byFlow)
- Packaging, Fixtures, Tooling (Materialise)

3D printing addresses:

- Downtime from part failures
- Customization needs
- Niche packaging and food-grade tooling

**Resilience Capabilities**

*Table 26: Resilience capabilities for 3D printing in agrifood.*

| Capability | Description |
|---|---|
| **Adaptability** | Rapid on-site creation of critical components |
| **Compliance** | EC-certified printing ensures regulatory conformity |
| **Customization** | Specialized tools for local and seasonal use |

Oceanz: A European SME specializing in food-safe 3D printed machines that address equipment disruptions and customization needs in food production. Oceanz supports localized part manufacturing and rapid prototyping in agri-food facilities.

byFlow: Offers portable 3D food printers designed for chefs and caterers. Its devices support innovative food presentation and production while addressing labor shortages through automation in culinary processes.

Materialise: Provides advanced 3D printing for packaging, tooling, and food production fixtures. It contributes to resilient food manufacturing by offering customized solutions where infrastructure limitations or low digital maturity hinder flexibility.

**Adoption Barriers**

*Table 27: Adoption barriers for 3D printing in agrifood.*

| Barrier | Explanation |
|---|---|
| **Cost** | High initial investment |
| **Material limitations** | Material compatibility |
| **Technical expertise** | Tech knowledge required |

Although still at a niche level, 3D printing presents a strategic advantage for localizing tool production, extending equipment life, and customizing packaging. These capabilities contribute to adaptability and operational continuity in the wine supply chain. However, the high initial cost, technical know-how, and certification requirements continue to limit broader use. Investment in open-source templates and training programs for farm-scale printers may increase relevance and impact.

### 2.1.2.6 Summary of digital maturity in agrifood

*Table 28: Digital maturity in agrifood*

| Technology | Maturity | Impact | Key Applications | Resilience Capabilities | Adoption Barriers |
|---|---|---|---|---|---|
| **AI** | High-Medium | Strategic | Demand forecasting, crop monitoring, soil analytics, predictive maintenance | Adaptability, Efficiency, Visibility, Flexibility | Infrastructure cost, skill gaps, data reliability, integration with legacy systems |
| **IoT** | Medium | Strategic | Input automation, irrigation control, condition monitoring, logistics tracking | Efficiency, Visibility, Respond, Adaptability | Connectivity, CAPEX, cybersecurity, maintenance network complexity |
| **Blockchain** | Medium | Strategic | Traceability, secure payments, provenance certification, NFT for regenerative farming | Visibility, Adaptability, Efficiency, Transform | Data literacy, interoperability, stakeholder resistance, privacy |
| **Data Spaces** | Medium-Low | Strategic | Shared ingredient and compliance platforms, real-time quality transparency | Visibility, Compliance, Efficiency, Adaptability | System onboarding, regulatory alignment, legacy system integration |
| **3D Printing** | Medium-Low | Strategic-Niche | Spare parts for machines, food-safe tooling, custom packaging | Adaptability, Compliance, Customization, Visibility | High cost, material compatibility, certification needs, tech knowledge |

### 2.1.3 Textile ecosystem: shoe and apparel sector

The textile ecosystem is undergoing a significant digital transformation driven by the integration of advanced technologies across its globally distributed value chain. From raw material production to retail, each stage increasingly leverages digital tools to enhance traceability, responsiveness, and operational continuity. These technologies play a crucial role in strengthening resilience within the textile sector by enabling accurate demand forecasting, agile supply chain reconfiguration, and rapid response to disruptions. This assessment identifies the maturity, application areas, resilience contributions, and adoption barriers of seven key technologies in the textile context, based solely on the findings from Deliverable D2.2.

#### 2.1.3.1 Artificial Intelligence (AI) in textile

**Maturity Level: Low**

- While AI contributes to resilience capabilities like adaptability, flexibility, visibility, and efficiency, its technology maturity level remains low—with most solutions still in early-stage development, pilot projects, or limited adoption.

**Impact Level: Strategic**

- Since the maturity level is still low, the potential impact of AI in the textile sector remains unclear; while AI holds strategic promise, broader deployment and tangible results will depend on overcoming key structural and technical barriers.

**Applications in Textile**

AI is emerging as a **strategically important** technology in the Textile ecosystem, supporting key functions such as demand forecasting, quality control, predictive maintenance, and supply chain optimization. According to D2.2, key applications include:

- AI-Powered Demand Forecasting Helps Adjust Production Based on Market Trends (e.g. Blue Yonder).
- Machine Learning for Quality Control through computer vision systems allows Dynamic Response to Quality Issues (e.g. Blue Yonder).
- Predictive Maintenance Ensures Quick Adaptation to Machinery Issues (e.g. Blue Yonder).
- Supply Chain Optimization Tools Provide Real-Time Tracking and Transparency Across the Supply Chain (e.g. o9 Solutions).
- IOT And AI Integration Improves Data Visibility from Production to Delivery (e.g. o9 Solutions).
- AI In Inventory Management Reduces Waste and Optimizes Stock Levels. Robotic Process Automation (e.g. ToolsGroup).
- Automates Routine Tasks, Increasing Operational Efficiency. (e.g. ToolsGroup).

These applications respond to key resilience challenges in the Textile ecosystem, including rapid changes in demand and production.

**Resilience Capabilities**

AI contributes to several resilience dimensions:

*Table 29: Resilience capabilities for AI in textile.*

| Capability | Description |
|---|---|
| **Adaptability** | Enables dynamic adjustment of processes and decisions in response to changing conditions and unexpected events. |
| **Flexibility** | Allows seamless reconfiguration of resources, workflows, and strategies to meet evolving demands and priorities. |
| **Visibility** | Enables real-time data integration, monitoring, and predictive insights. |
| **Efficiency** | Enables process automation and resource optimization to reduce waste, save time, and improve operational performance |

Examples found in D2.2:

- **Blue Yonder:** Uses AI-powered demand forecasting to align production with market trends; applies machine learning for quality control and predictive maintenance to enhance operational resilience (Table 1).
- **o9 Solutions:** Provides supply chain optimization tools for real-time tracking and transparency; integrates IoT and AI to improve data visibility from production to delivery (Table 1).
- **ToolsGroup:** Implements AI-driven inventory management to minimize waste and maintain optimal stock levels; leverages Robotic Process Automation (RPA) to streamline repetitive operations and boost overall efficiency (Table 1).

**Adoption Barriers**

Despite its maturity, AI adoption in the Textile ecosystem faces several challenges:

*Table 30: Adoption barriers for AI in Textile.*

| Barrier | Explanation |
|---|---|
| **Integration with Legacy Systems** | Difficulty connecting AI tools with outdated machinery and software. |
| **Data privacy concerns** | Risks related to handling sensitive production or customer data. |
| **High Infrastructure and Implementation Cost** | Significant upfront investment in AI technologies and infrastructure. |
| **Skills and Training Needs** | Lack of in-house expertise to develop, manage, and interpret AI systems. |

These barriers are consistent with those identified across ecosystems.

As conclusion, Artificial Intelligence presents **promising opportunities** for enhancing resilience in the Textile ecosystem, particularly through capabilities such as adaptability, flexibility, visibility, and efficiency. Technologies like computer vision for visual inspection enable automated, real-time quality control, significantly improving defect detection and reducing manual errors. However, its low maturity level and the presence of significant adoption barriers limit its current diffusion. As a result, while the strategic potential of AI is acknowledged, its actual impact remains uncertain and largely untapped.

#### 2.1.3.2 Internet of Things (IoT) in textile

**Maturity Level: Medium**

- IoT in the textile sector has a medium level of technological maturity, contributing to resilience capabilities such as adaptability, efficiency, visibility, redundancy, market strength, and responsiveness.

**Impact Level: Strategic**

- IoT is considered to have strategic impact in the textile sector because it enables structural transformations in the production chain, such as real-time traceability, process automation, and agile response to disruptions - strengthening the sector's competitiveness and resilience.

**Applications in Textile**

According to D2.2, key applications include:

- Smart Factory Integration with Edge-Enabled Real-Time Machine Health Monitoring (e.g. Siemens AG)
- RFID/BLE Tagging & Sensor Network for Full Traceability and Resource Tracking (e.g. UBI Solutions)
- ERP-Integrated Shop-Floor Sensors Feeding Real-Time Production Dashboards (e.g. Datatex)

These applications are aligned with the resilience needs identified in the Textile ecosystem such as:

- Adaptability and efficiency through predictive maintenance and rapid response.
- Visibility, redundancy, and market strength through end-to-end traceability.
- Agile response and efficiency with ERP-integrated sensors.

**Resilience Capabilities**

IoT contributes to several resilience dimensions:

*Table 31: Resilience capabilities for IoT in textile.*

| Capability | Description |
|---|---|
| **Adaptability** | Allows textile factories to dynamically adjust to operating conditions by monitoring machine health in real time and anticipating failures, enabling rapid production reconfigurations. |
| **Efficiency** | The integration of sensors feeds planning and quality dashboards with real-time data, optimizing processes and reducing waste. |

| | |
|---|---|
| **Visibility** | Use of sensors that provide full visibility of the production chain, essential for data-driven decision-making. |
| **Redundance** | Detailed traceability and resource consumption monitoring at each production stage allow for the identification of bottlenecks and the planning of operational and input redundancies. |
| **Market Strenght** | The digitalization of workflows with IoT and real-time data collection help textile companies respond quickly to market demands, strengthening their competitive position through traceability and transparency. |
| **Respond** | The automatic feeding of production metrics via sensors accelerates the identification of deviations and enables swift responses to disruptions or failures in the production process. |
| **Adaptability** | Allows textile factories to dynamically adjust to operating conditions by monitoring machine health in real time and anticipating failures, enabling rapid production reconfigurations. |

Examples found in D2.2:

- **Siemens AG:** Integrates sensors, machines, and ERP into a smart factory, with real-time monitoring and predictive maintenance alerts via edge IoT.
- **UBI Solutions:** Digitizes production workflows with RFID/BLE sensors and tracks resource consumption at each stage of production.
- **Datatex:** Integrates IoT sensors with ERP, feeding real-time production metrics for planning and quality.

**Adoption Barriers**

Despite its growing maturity, IoT adoption in the Textile ecosystem faces several challenges

*Table 32: Adoption barriers for AI in Textile.*

| Barrier | Explanation |
|---|---|
| **Legacy system integration** | Many textile companies use old, customized systems that do not easily connect with modern technologies. |
| **High implementation costs** | Some companies, especially small and medium-sized ones, operate with low profit margins and limited financial resources. |
| **Connectivity Challenges** | Limited connectivity in peripheral industrial regions hinders the adoption of digital technologies in the textile sector, compromising traceability, automation, and resilience. |
| **Supplier Participation Reluctance** | Many European textile suppliers, especially smaller ones, are reluctant to adopt digital technologies due to limited resources, technical knowledge, or a clear perception of benefits. |
| **ERP Integration Complexity** | The complexity of integrating new digital solutions with existing ERP systems hinders sector digitalization, given the variety of legacy platforms and lack of standardization. |

| | |
|---|---|
| **Scalability Constraints** | Technological solutions are often not easily scalable for small and medium-sized textile enterprises, limiting their adoption in fragmented and diverse supply chains. |

These barriers are consistent with those identified across ecosystems (Section 3.1.2).

As conclusion, the adoption of IoT technologies in the textile sector demonstrates **strong alignment** with key resilience capabilities such as adaptability, efficiency, visibility, redundancy, market strength, and responsiveness. These technologies enable real-time monitoring, predictive maintenance, traceability, and data-driven decision-making, which are crucial for strengthening supply chain resilience. However, widespread adoption remains challenged by structural and technical barriers, including legacy system integration, high implementation costs, connectivity limitations, ERP integration complexity, supplier reluctance, and scalability constraints, particularly for SMEs. Addressing these barriers is essential to unlocking the full potential of IoT for enhancing resilience in the European textile ecosystem.

### 2.1.3.3 Blockchain in textile

**Maturity Level: Low**

- Despite promising use cases, blockchain adoption in the textile sector remains limited due to high implementation costs, low digital literacy among stakeholders, and concerns over interoperability and data privacy. These barriers hinder widespread deployment and integration into existing supply chain systems.

**Impact Level: Transformative**

- When implemented, blockchain has the potential to transform the textile industry by enabling end-to-end transparency, authenticating sustainability claims, and supporting decentralized business models, thereby strengthening resilience and fostering trust across the value chain.

**Applications in Textile**

As described in D2.2, Blockchain is used in Textile to:

- Fiber Traceability and Cryptographic Verification for Premium Textiles (e.g. Textile Genesis).
- Full Lifecycle Authenticity & Compliance with Smart Contracts (e.g. Aura Blockchain Consortium).
- Sustainability Claims Auditing and Tokenized Credentials (e.g. Provenance).
- Plug-And-Play Blockchain-As-A-Service (Baas) For Fast Traceability (e.g. icommunity).
- Customer-Facing Transparency Platforms to Boost Trust and Brand Engagement (e.g. Aura Blockchain Consortium).
- Support for Digital Product Passports and ESG Compliance through Immutable Data Sharing.

These applications address resilience priorities in the Textile ecosystem, including the need for sustainable and high-quality products.

**Resilience Capabilities**

Blockchain contributes to several resilience dimensions:

*Table 33: Resilience capabilities for IoT in textile.*

| Capability | Description |
|---|---|
| Visibility | Provides end-to-end traceability and real-time transparency across the supply chain. |
| Adaptability | Enables flexible integration with diverse stakeholders and evolving regulatory requirements. |
| Efficiency | Automates compliance checks and data validation through smart contracts and digital credentials. |
| Market Strength | Builds consumer trust and brand value through verified sustainability and authenticity. |
| Transform | Lays the foundation for new business models based on decentralized, transparent, and tokenized ecosystems. |

Examples found in D2.2:

- **Textile Genesis:** Enables radical transparency and verifies the authenticity of sustainable, premium textiles like wood-based fibers, cotton, silk, wool, and cashmere.
- **Aura Blockchain Consortium:** Uses Blockchain to tackle challenges related to authenticity, responsible sourcing, and sustainability, providing transparency and enhanced customer experiences across the entire product lifecycle.
- **Provenance:** Validates sustainability claims in the textile industry, helping multi-brand retailers and their partners comply with regulations, capture green growth opportunities, and future-proof their competitiveness.
- **icommunity:** Facilitates digital transformation with a plug-and-play Blockchain-as-a-Service (iBS) platform, offering multi-chain solutions to accelerate projects without the need to manage infrastructure.

**Adoption Barriers**

Despite its maturity, Blockchain adoption in the Textile ecosystem faces several challenges:

*Table 34: Adoption barriers for blockchain in Textile.*

| Barrier | Explanation |
|---|---|
| High Infrastructure and Implementation Cost | Initial setup and integration of blockchain solutions require significant financial investment. |
| Skills and Training Needs | Limited understanding of blockchain among supply chain actors slows adoption. |

| | |
|---|---|
| **Interoperability challenges** | Difficulty connecting blockchain systems across different platforms and organizations. |
| **Regulation uncertainty** | Lack of clear and consistent regulatory frameworks for blockchain use in textiles. |
| **Data Privacy concerns** | Fears around sharing sensitive product and supplier data on distributed ledgers. |
| **Resistance to Change** | Reluctance to expose supply chain data and inertia due to established practices or legacy systems. |
| **Security Concerns** | Risks of cyberattacks or misuse of data within blockchain environments remain a barrier. |

These barriers are consistent with those identified across ecosystems

As conclusion, in the textile ecosystem, **blockchain holds transformative potential** by addressing critical resilience priorities such as transparency, compliance, and sustainability. Blockchain-backed traceability enables tamper-proof certification throughout the entire supply chain, from fiber origin to finished product. When combined with digital product passports, this technology becomes essential for enhancing trust, ensuring regulatory compliance, and promoting sustainable practices, positioning blockchain as a key driver of resilience and innovation in the textile industry.

### 2.1.3.4 Data spaces in textile

**Maturity Level: Medium**

- Data space technology in the textile sector has a medium level of maturity, as there are ongoing initiatives and platforms under development, but adoption remains limited due to technical barriers such as integration with legacy systems.

**Impact Level: Strategic**

- Data space in the textile sector is considered to have strategic impact because it enables standardized and secure data sharing among supply chain actors, promoting visibility, traceability, and collaboration, key elements for enhancing the sector's resilience and competitiveness.

**Applications in Textile**

According to D2.2, key applications include:

- Interoperable digital platforms (e.g. EURATEX).

These applications are aligned with the resilience needs identified in the Textile ecosystem such as:

- Enhancing visibility across the supply chain
- Improving adaptability and responsiveness

**Resilience Capabilities**

Data Space contributes to several resilience dimensions:

*Table 35: Resilience capabilities for data spaces in textile.*

| Capability | Description |
|---|---|
| **Visibility** | Provide a secure and standardized digital environment for data sharing among different actors in the supply chain. |

Examples found in D2.2:

- **EURATEX:** Enables Standardized Data Sharing Across Textile Supply Chains

**Adoption Barriers**

Despite its growing maturity, Data Space adoption in the Textile ecosystem faces several challenges:

*Table 36: Adoption barriers for data spaces in Textile.*

| Barrier | Explanation |
|---|---|
| **Integration With Legacy ERP Systems** | Old systems, often customized and non-standardized, hinder the secure and structured sharing of data in collaborative digital environments. |

These barriers are consistent with those identified across ecosystems (Section 3.1.2).

As conclusion, interoperable digital platforms support key resilience needs in the textile sector by enhancing visibility and enabling more adaptive, responsive supply chains through standardized data sharing. However, integration with legacy ERP systems remains a major barrier, limiting the full potential of data spaces in strengthening ecosystem resilience.

### 2.1.3.5 AR/VR in textile

**Maturity Level: Low**

- AR/VR technologies in the Textile ecosystem are still in early adoption stages, hindered by high implementation costs, integration challenges with legacy systems, and the need for specialized training. These barriers limit widespread deployment, especially among smaller industry players.

**Impact Level: Transformative**

- Despite limited maturity, AR/VR applications enable transformative shifts in business models, such as virtual retail, remote operations, and immersive training, fundamentally changing how customer engagement, supply chain planning, workforce preparedness, and worker well-being are approached.

**Applications in Textile**

As described in D2.2, AR/VR technologies are being applied in the Textile ecosystem to:

- AR and AI platforms for virtual clothing try-ons and shopping personalization (e.g. Wearfits).
- Immersive VR exhibitions and AR-based retail enhancements to improve customer experience (e.g. Innowise).
- AR smart glasses to support warehousing operations and remote assistance (e.g. Vuzix).
- VR software for planning and simulating warehouse layouts in virtual environments (e.g. Hellmann).

These applications are aligned with the resilience needs identified in the Textile ecosystem such as:

- Rapid Changes in Demand and Production
- Emerging Consumption Patterns (Online & On-Demand Shopping)

**Resilience Capabilities**
AR/VR technologies contribute to several resilience dimensions:

*Table 37: Resilience capabilities for data spaces in textile.*

| Capability | Description |
|---|---|
| **Market Strength** | Enhances customer engagement and brand differentiation through immersive and personalized experiences. |
| **Transform** | Enables new business models such as virtual retail, digital showrooms, and remote operations. |
| **Adaptability** | Supports flexible response to changing consumer behaviors and operational demands. |
| **Efficiency** | Optimizes logistics, training, and layout planning, reducing costs and improving decision-making. |

Examples found in D2.2:

- **Wearfits**: A digital platform combining AR, AI, and 3D visualization to enable virtual try-ons for clothing and footwear, based on user images or measurements. It enhances the online shopping experience and reduces returns.
- **Innowise:** Used to improve customer experience through immersive virtual store tours, 360° product exhibitions, and VR training apps across various industries.
- **Vuzix:** Improve warehousing and manufacturing efficiency by providing real-time access to instructions, documentation, and remote assistance.
- **Hellmann:** Software tools that allow the full design and simulation of warehouse layouts in virtual environments.

**Adoption Barriers**
Despite promising applications, **AR/VR adoption** in the Textile ecosystem faces several challenges:

*Table 38: Adoption barriers for data spaces in Textile.*

| Barrier | Explanation |
|---|---|
| **Data privacy concerns** | Risks related to collecting and processing user data, especially in personalized retail experiences. |
| **Integration with Legacy Systems** | Difficulty in aligning AR/VR tools with existing IT infrastructures and processes. |
| **High Infrastructure and Implementation Cost** | High investment required for hardware, software, and digital content creation, with AR/VR device and license costs potentially prohibitive for smaller actors. |
| **Skills and Training Needs** | Effective use of AR/VR tools requires specific skills and employee training, often lacking in the sector. |

These barriers are consistent with those identified across ecosystems.

As conclusion, While AR/VR adoption faces significant obstacles, its **potential to revolutionize** customer experiences, operational processes, and workforce training positions these technologies as key drivers for future resilience and innovation in the Textile industry. Strategic investments and overcoming barriers, including those related to training and worker well-being, will be crucial to unlocking their full impact.

### 2.1.3.6 Robotics in textile

**Maturity Level: Low**

- Robotics still has low penetration in the textile sector due to the predominance of manual processes, high implementation costs, and infrastructure limitations in factories, especially among SMEs.

**Impact Level: Strategic**

- It is considered to have strategic impact because it can significantly transform productivity, quality, and operational flexibility, increasing the competitiveness and resilience of the textile supply chain in the face of disruptions.

**Applications in Textile**

According to D2.2, key applications include:

- Automated cutting, sewing, and handling (e.g. ABB Robotics).
- AI-based sorting and recycling (e.g. Robotextile).
- Robotic arms for sewing and handling (e.g. Yaskawa Robotics).
- High-precision robotics for weaving and cutting (e.g. Stäubli Robotics).

These applications are aligned with the resilience needs identified in the Textile ecosystem such as:

- Need for efficiency, High-Quality Products
- Generating market responsiveness

**Resilience Capabilities**

Robotics contributes to several resilience dimensions:

*Table 39: Resilience capabilities for robotics in textile.*

| Capability | Description |
| --- | --- |
| **Adaptability** | Robots enable quick reconfiguration of production processes in response to demand shifts or disruptions, increasing operational flexibility. |
| **Efficiency** | Automating tasks such as cutting, sewing, and handling reduces time, errors, and waste—optimizing resource use and boosting productivity. |
| **Visibility** | Robotic solutions integrated with digital systems allow precise tracking and monitoring of production stages, enhancing control and transparency. |
| **Market strength** | The ability to produce with quality, speed, and sustainability strengthens the competitiveness of textile companies in the European market, meeting both regulatory and consumer demands. |

Examples found in D2.2:

- **ABB Robotics:** ABB provides robotic automation for textile cutting, sewing, and handling, improving speed and consistency in textile manufacturing.
- **Robotextile:** Provides AI-driven robotic solutions for textile sorting, recycling, and production line automation.
- **Yaskawa Robotics:** Offers high-speed robotic arms for textile handling and automated fabric stitching.
- **Stäubli Robotics**: Specializes in high-precision robotic solutions for weaving, fabric cutting, and handling.

**Adoption Barriers**

Despite its growing maturity, Robotics adoption in the Textile ecosystem faces several challenges:

*Table 40: Adoption barriers for robotics in Textile.*

| Barrier | Explanation |
| --- | --- |
| **High Investment** | Implementing robotics requires high initial investments, often unaffordable for SMEs. |
| **Workforce Retraining** | The workforce needs to be reskilled to operate and interact with robotic systems. |
| **System Integration** | Integrating robots into existing systems is technically complex and resource-intensive. |
| **Resistance in Legacy Factories** | Factories with outdated infrastructure tend to resist adopting new technologies. |
| **Job Displacement Concerns** | There are concerns about manual jobs being replaced by automation. |

| | |
|---|---|
| **Training Needs** | The lack of technical training programs limits the preparation of qualified professionals. |
| **Maintenance Costs** | Maintaining robotic equipment can be expensive and requires specialized support. |
| **Workforce Training for Advanced Robotics** | Specific training for operating advanced robotics is still limited and costly. |

These barriers are consistent with those identified across ecosystems (Section 3.1.2).

As conclusion, the adoption of robotics in the European textile sector plays a **strategic role** in strengthening resilience by addressing key needs such as efficiency, high-quality production, and responsiveness to market changes. However, despite its transformative potential, the sector still faces significant adoption barriers, especially among SMEs, including high investment costs, the need for workforce reskilling, system integration challenges, and limited access to specialized training.

#### 2.1.3.7 3D printing in textile

**Maturity Level: Medium**

- While 3D printing in textiles is gaining traction with scalable solutions and commercial applications, widespread adoption is hindered by integration challenges, high initial costs, and the need for specialized skills.

**Impact Level: Transformative**

- 3D printing enables on-demand, zero-waste, and customizable textile production, supporting adaptability, efficiency, and innovation, key dimensions for building resilient and sustainable textile ecosystems.

**Applications in Textile**

According to D2.2, key applications include:

- Zero-Waste, Hyperlocal 3D Knitting Via LOOP™ CAD/CAM Software (e.g. VARIANT3D).
- Custom 3D Printing for Textile Design and Rapid Prototyping (e.g. Sculpteo).
- Industrial-Scale 3D Printing for Prototyping and Textile Fabrication (e.g. Stratasys).

These applications are aligned with the resilience needs identified in the Textile ecosystem such as:

- Rapid Changes in Demand and Production
- Need for Sustainable, High-Quality Products
- Emerging Consumption Patterns (Online & On-Demand Shopping)

**Resilience Capabilities**

3D Printing contributes to several resilience dimensions:

*Table 41: Resilience capabilities for 3D printing in textile.*

| Capability | Description |
|---|---|
| **Adaptability** | Enables rapid adjustment of production volumes and designs in response to changing demand. |
| **Efficiency** | Reduces waste and optimizes material usage through additive manufacturing. |
| **Flexibility** | Supports on-demand production and product customization. |
| **Innovation** | Facilitates new design possibilities and business models, enhancing competitiveness. |

Examples found in D2.2:

- **VARIANT3D:** The LOOP™ 3D CAD/CAM application supports a more sustainable and collaborative manufacturing ecosystem, leading the textile industry with hyperlocal, zero-waste, and customizable 3D knitting technology.
- **Sculpteo:** Online 3D printing services tailored to the textile industry enable the creation of tailor-made, customizable products. A wide range of materials supports innovative designs and structures.
- **Stratasys:** Advanced industrial 3D printing solutions for textile manufacturing and rapid prototyping.

**Adoption Barriers**

Despite its growing maturity, 3D Printing adoption in the Textile ecosystem faces several challenges:

*Table 42: Adoption barriers for 3D printing in Textile.*

| Barrier | Explanation |
|---|---|
| **Integration with Legacy Systems** | Compatibility and workflow alignment remain complex. |
| **High Infrastructure and Implementation Cost** | Significant investment is required for industrial-grade 3D printers and materials. |
| **Material And Design Limitations** | Not all textile properties or aesthetics can be replicated using current 3D printing materials. |
| **Skills and Training Needs** | Operating and designing for 3D printing requires specialized knowledge and training. |

These barriers are consistent with those identified across ecosystems (Section 3.1.2).

As conclusion, 3D printing represents a **pivotal technological shift** for the textile sector, offering high-impact capabilities that align with future resilience needs. However, its transformative potential will only be fully realized by overcoming current adoption barriers through investment, training, and system integration.

### 2.1.3.8 Summary of digital maturity in textile

*Table 43: Digital maturity in textile.*

| Technology | Maturity | Impact | Key Applications | Resilience Capabilities | Adoption Barriers |
|---|---|---|---|---|---|
| **AI** | Low | Strategic | AI-Powered Demand Forecasting; Machine Learning for Quality Control; Predictive Maintenance with AI; Supply Chain Optimization with Real-Time Tracking; IoT and AI Integration; AI in Inventory Management; Automation of Routine Tasks | Adaptability, flexibility, visibility and efficiency. | Integration with Legacy Systems; Data privacy concerns; High Infrastructure and Implementation Cost; Skills and Training Needs. |
| **Blockchain** | Low | Transformative | Fiber Traceability and Cryptographic Verification for Premium Textiles; Full Lifecycle Authenticity & Compliance with Smart Contracts; Sustainability Claims Auditing and Tokenized Credentials; Plug-And-Play Blockchain-As-A-Service (Baas) For Fast Traceability; Customer-Facing Transparency Platforms to Boost Trust and Brand Engagement; Support for Digital Product Passports and ESG Compliance through Immutable Data Sharing. | Capability; Visibility; Adaptability; Efficiency; Market Strength and Transform | High Infrastructure and Implementation Cost; Skills and Training Needs; Interoperability challenges; Regulation uncertainty; Data Privacy concerns; Resistance to Change; Security Concerns and These barriers are consistent with those identified across ecosystems. |
| **AR/VR** | Low | Transformative | AR and AI platforms for virtual clothing try-ons and shopping personalization; Immersive VR exhibitions and AR-based retail enhancements to improve customer experience; AR smart glasses to support warehousing operations and remote assistance and VR software for planning and simulating warehouse layouts in virtual environments (e.g. Hellmann). | Market strength; transform; adaptability; efficiency. | Data privacy concerns; Integration with Legacy Systems; High Infrastructure and Implementation Cost; Skills and Training Needs and These barriers are consistent with those identified across ecosystems. |
| **3D printing** | Medium | Transformative | Zero-Waste, Hyperlocal 3D Knitting Via LOOP™ CAD/CAM Software; | Adaptability, efficiency, | Integration with Legacy Systems; High |

| | | | | | |
|---|---|---|---|---|---|
| | | | Custom 3D Printing for Textile Design and Rapid Prototyping; Industrial-Scale 3D Printing for Prototyping and Textile Fabrication. | flexibility and innovation | Infrastructure and Implementation Cost; Material And Design Limitations; Skills and Training Needs |
| **IoT** | Medium | Strategic | Smart Factory Integration with Edge-Enabled Real-Time Machine Health Monitoring; • RFID/BLE Tagging & Sensor Network for Full Traceability and Resource Tracking; ERP-Integrated Shop-Floor Sensors Feeding Real-Time Production Dashboards | Adaptability, efficiency, visibility, redundance, market strength and respond. | Legacy system integration; High implementation costs; Connectivity Challenges; Supplier Participation Reluctance; ERP Integration Complexity; Scalability Constraints |
| **Data Space** | Medium | Strategic | Enhancing visibility across the supply chain and Improving adaptability and responsiveness | Visibility | Integration With Legacy ERP Systems |
| **Robotics** | Low | Strategic | Automated cutting, sewing, and handling; AI-based sorting and recycling ; Robotic arms for sewing and handling; High-precision robotics for weaving and cutting. | Adaptability; efficiency; visibility; market strength. | High Investment; Workforce Retraining; System Integration; Resistance in Legacy Factories; Job Displacement Concerns; Training Needs; Maintenance Costs; Workforce Training for Advanced Robotics |

### 2.1.4 Digital maturity in the automotive ecosystem: electric vehicles

The automotive sector is undergoing dynamic change driven by the integration of advanced digital technologies. These technologies are crucial for improving efficiency, resilience, and innovation within the industry. This document assesses the maturity, areas of application, contributions to resilience, and barriers to adoption of ten key technologies in the context of the automotive sector, based on the results of Deliverable D2.2 of the RISE-SME project.

#### 2.1.4.1 Artificial Intelligence (AI) in automotive

**Maturity Level: High**

- AI technologies are widely implemented across the automotive sector, demonstrating proven effectiveness in enhancing efficiency, automating processes, and improving decision-making.

**Impact Level: Transformative**

- AI fundamentally changes operations in the automotive sector by enabling automation, enhancing decision-making, and improving customer experiences.

**Applications in the automotive sector**

AI is central to the operation and evolution of The Automotive Sector platforms. According to D2.2, key applications include:

- **Automated driving integration:** AI enables perception, decision-making, and control systems for self-driving vehicles (Table 4).
- **Predictive maintenance:** AI models analyze vehicle data to anticipate maintenance needs (Section 2.1.2, DIGITAL TWIN).
- **Production optimization:** AI algorithms enhance production planning and scheduling (Section 2.1.1).

These applications align with the resilience needs identified in the automotive ecosystem, such as:

- Adapting to changing production conditions
- Predicting maintenance needs to avoid delays
- Ensuring compliance with safety and environmental regulations

**Resilience Capabilities**

AI contributes to several resilience dimensions:

*Table 44: Resilience capabilities for AI in automotive.*

| Capability | Description |
|---|---|
| **Adaptability** | AI enhances adaptability by enabling real-time data analysis and decision-making, allowing automotive systems to adjust quickly to changing conditions and demands. |
| **Efficiency** | It improves operational efficiency through automation and optimization of processes, leading to reduced costs and enhanced productivity. |
| **Visibility** | AI provides increased visibility into operations by analyzing data from various sources, enabling better tracking and monitoring of processes and assets. |

Examples found in D2.2:

- **NVIDIA:** Provides AI-powered solutions for autonomous driving, manufacturing optimization, and in-vehicle experiences (Table 4)

- **Mobileye:** AI-powered computer vision solutions for automotive manufacturing and autonomous vehicles (Table 4)
- **Impel:** Offers AI-Powered Customer Lifecycle Management Platforms for the Automotive Industry (Table 4)

**Adoption Barriers**

Despite its maturity, AI adoption in The Automotive Sector faces several challenges:

*Table 45: Adoption barriers for AI in automotive.*

| Barrier | Explanation |
|---|---|
| **High Implementation Costs** | Significant upfront investments needed to integrate new technologies can deter organizations, especially smaller ones. |
| **Integration Complexity** | Challenges integrating new solutions with existing systems can lead to operational disruptions and increased costs. |
| **Need for Specialized Expertise** | Requires skilled personnel with expertise in advanced technologies, which can be a barrier to implementation. |
| **Integration with Existing CRM Systems** | Compatibility issues with current CRM systems can hinder seamless adoption of new technologies. |
| **Data Security Concerns** | Concerns about data privacy and security can prevent organizations from fully adopting new technologies. |

These barriers are consistent with those identified across ecosystems.

In conclusion, artificial intelligence is a **mature and transformative** technology in the automotive sector ecosystem. It directly addresses key resilience challenges by enabling:

- Real-time, adaptive production processes are essential for the modern business environment.
- Predictive maintenance and optimization of the supply chain.
- The process of integrating logistics and manufacturing systems has been enhanced.

To achieve its full potential, it is essential to overcome barriers related to integration with legacy systems, high implementation costs, and regulatory uncertainties.

### 2.1.4.2 Blockchain in automotive

**Maturity Level: Medium**

- It has demonstrated practical applications, such as improving supply chain traceability and enabling secure data sharing, it has not yet been widely adopted across all industry segments. Many organisations are still in the exploratory or pilot phase, grappling with integration issues involving legacy systems and navigating regulatory uncertainties.

**Impact Level: Strategic**

- It supports key functions and improvements in resilience and operations, such as increasing transparency, streamlining recall processes and protecting data transactions. But it has not yet fundamentally transformed the automotive sector, rather, it serves as a powerful tool for enhancing existing processes and systems.

**Applications in the automotive Sector**

As described in Table 13 (p. 38) and T2.3 Excel file, Blockchain is used in the automotive sector to:

- **Real-Time Part Tracking:** Monitors vehicle parts during manufacturing and logistics, optimizing recall processes
- **Recall Optimization**: Streamlines recalls by quickly identifying defective parts, minimizing risks and costs.
- **Secure Data Ledger**: Provides an immutable blockchain database for vehicle data, ensuring data integrity.
- **Supply Chain Monitoring**: Enhances visibility and accountability across the supply chain.
- **Full Component Traceability**: Tracks vehicle components with cryptographic records to ensure authenticity.
- **Telematics Security**: Secures telematics data through decentralized identity and transactions.

These applications are aligned with the resilience needs identified in the automotive ecosystem, such as:

- Ensuring compliance with safety and environmental regulations
- Enhancing transparency and trust among supply chain partners
- Rapid identification and response to recalls or safety issues

**Resilience Capabilities**

Blockchain contributes to several resilience dimensions (T2.3 Excel file):

*Table 46: Resilience capabilities for blockchain in automotive.*

| Capability | Description |
|---|---|
| **Adaptability** | Blockchain technologies enable rapid adjustments to supply chain processes in response to disruptions. |
| **Efficiency** | Automates processes such as recall management and compliance, reducing operational overhead. |
| **Respond** | Enhances the ability to quickly identify and react to issues, such as defective parts or compliance breaches. |
| **Financial Strength** | Reduces costs associated with recalls and inefficiencies through improved data management and traceability. |
| **Transform** | Facilitates innovative business models, such as decentralized identity and transactions, enhancing competitiveness. |
| **Visibility** | Provides transparent tracking of vehicle parts and components throughout the supply chain. |
| **Redudance** | Supports decentralized data storage, ensuring data availability even if one part of the system fails. |

Examples found in D2.2:

- **Aetsoft:** Offers a private blockchain database for secure, tamper-proof vehicle data, smart contract recalls alerts, and real-time parts tracking.
- **Nextrope:** Provides smart-contract-driven supply chain monitoring and an immutable automotive data ledger for enhanced traceability.
- **Fista Solutions:** Utilizes a distributed ledger for end-to-end component traceability, ensuring cryptographic provenance records.
- **Cellport:** Delivers blockchain-managed telematics data security, decentralized identity authentication, and immutable transaction logging.

**Adaption Barrier**

Despite its maturity, Blockchain adoption in the automotive ecosystem faces several challenges:

*Table 47: Adoption barriers for blockchain in automotive.*

| Barrier | Explanation |
|---|---|
| **Integration with Legacy Systems** | Difficulty in integrating Blockchain solutions with existing legacy automotive infrastructure. |
| **Regulatory Uncertainty** | Lack of clear regulations and guidelines concerning data privacy, security, and Blockchain applications. |
| **Expertise Gap** | Shortage of expertise in the automotive domain to implement and manage Blockchain solutions effectively. |
| **Performance Bottlenecks** | Real-time performance constraints may arise due to the complexity of Blockchain transactions. |
| **Customization Complexity** | Challenges in customizing Blockchain solutions to fit specific automotive applications and processes. |
| **High Initial Investment** | Significant upfront costs associated with implementing Blockchain technology in automotive processes. |
| **Compliance Certification** | Need for certification and compliance that can complicate the adoption of Blockchain solutions |
| **Legacy Integration Hurdles** | Difficulties in integrating Blockchain with existing vehicle systems and processes. |

These barriers are consistent with those identified across ecosystems.

In conclusion, blockchain technology offers significant opportunities to enhance resilience in the automotive sector. It addresses critical challenges such as supply chain transparency and recall optimisation by enabling real-time part tracking and secure data sharing. Key players such as Aetsoft and Nextrope offer solutions that streamline processes and improve accountability throughout the supply chain.

However, there are still barriers to adoption, including integration with legacy systems, the need for high initial investments, and regulatory uncertainties. Overcoming these challenges is essential to realise the full potential of blockchain technology in driving innovation and efficiency within the automotive ecosystem.

### 2.1.4.3 Digital Twin in automotive

**Maturity Level: Medium**

- Its use is successful, but not universal. Many are still piloting it, facing integration and training challenges with existing systems.

**Impact Level: Strategic**

- It enables functions and improvements in operations such as production workflow optimisation, predictive maintenance and "what-if" simulations. It has not fundamentally transformed the automotive sector yet.

**Applications in the automotive Sector**

As described in D2.2, Digital Twin is used in the automotive sector to:

- **Operational Strategy Evaluation:** Enables the assessment of operational strategies and forecasting the impact of disruptions.
- **Process Optimization:** Simulates machines, production lines, or entire factories in real time to optimize workflows before physical implementation.
- **Predictive Maintenance:** Analyzes real-time data to predict maintenance needs, reducing downtime and costs.
- **Virtual Training Environments:** Emulates production lines to support training in virtual environments, enhancing workforce readiness.
- **Immersive 3D Models:** Uses "what-if" simulations and immersive 3D models to uncover business insights and optimize production.

These applications align with the resilience needs identified in the automotive ecosystem, such as:

- Enhancing adaptability to changing production conditions.
- Improving efficiency in operations and maintenance.
- Supporting rapid response to operational challenges.

**Resilience Capabilities**

Digital Twin contributes to several resilience dimensions:

*Table 48: Resilience capabilities for digital twins in automotive.*

| Capability | Description |
|---|---|
| **Adaptability** | Allows for rapid adjustments to production processes and strategies based on real-time data and simulations. |
| **Efficiency** | Streamlines operations through process optimization and predictive maintenance, reducing waste and downtime. |
| **Visibility** | Provides enhanced visibility into production workflows and machine performance, facilitating informed decision-making. |

Examples found in D2.2:

- **Siemens:** Optimise workflows before physical implementation by simulating machines, production lines or entire factories in real time.
- **Rockwell Automation:** Emulates production lines and supports training in virtual environments, simulating performance changes
- **Royal HaskoningDHV:** Provides immersive 3D models and simulation tools that allow you to explore different scenarios and optimise production.

**Adaption Barriers**

Despite its growing maturity, Digital Twin adoption in the automotive ecosystem faces several challenges:

*Table 49: Adoption barriers for digital twins in automotive.*

| Barrier | Explanation |
|---|---|
| Integration with Legacy Systems | Digital Twin solutions are difficult to integrate with legacy systems and processes, creating data silos and inefficiencies. |
| Training Needs | Requirement for extensive training and skill development among employees to effectively utilize Digital Twin technology and optimize its application in operations. |

These barriers are consistent with those identified across ecosystems.

In conclusion, digital twin technology offers significant opportunities to enhance resilience in the automotive sector, particularly through improving adaptability, efficiency and visibility. It enables the real-time simulation and optimization of production processes, predictive maintenance and strategic operational evaluations.

Despite this, challenges such as integration with legacy systems and the requirement for extensive training can impede its widespread adoption. Although the strategic potential of digital twins is recognized, their current impact remains limited as organisations work to overcome these barriers. Although Digital Twin technology is set to transform operations, its full benefits have yet to be realized in the automotive industry.

### 2.1.4.4 Internet of Things (IoT) in automotive

**Maturity Level: Medium**

- Although IoT applications like predictive maintenance, real-time tracking and remote monitoring are growing in use, many organisations are still transitioning to these technologies and have not yet fully integrated them. Adoption is often limited to specific use cases.

**Impact Level: Strategic**

- The IoT is an essential tool for enhancing operational efficiency and responsiveness within the automotive sector. But challenges such as integration with legacy systems and data security are holding back the overall impact of IoT, despite its strategic potential.

**Applications in the automotive Sector**

As described in D2.2, IoT is used in the automotive sector to:

- **Predictive Maintenance:** Used to forecast maintenance needs, reducing downtime and optimising service schedules.
- **Real-Time Part Location:** RAIN RFID technology tracks parts throughout the supply chain, enabling efficient rerouting and inventory management.
- **Remote Work-Order Guidance**: Provides remote assistance and guided workflows, ensuring efficient operations and quick resolution.
- **Connected Robotics:** Integrates lot-connected robotics with self-diagnosis and plug-and-play architecture for production flexibility.
- **Status Tracking of Components:** Offers real-time status updates for improved visibility and traceability.

These applications align with the resilience needs identified in the automotive ecosystem, such as:

- Enhancing visibility and accountability in supply chain operations.
- Improving responsiveness to maintenance and operational challenges.
- Facilitating efficient resource allocation and process optimization.

**Resilience Capabilities**

IoT contributes to several resilience dimensions:

*Table 50: Resilience capabilities for IoT in automotive.*

| Capability | Description |
|---|---|
| **Adaptability** | Facilitates adaptability in production and logistics by allowing for real-time adjustments based on data insights. |
| **Redundancy** | Supports system redundancy through interconnected devices, ensuring continuous operations even during disruptions. |
| **Visibility** | Provides comprehensive visibility into supply chain processes, tracking parts and components in real time. |
| **Efficiency** | Enhances operational efficiency through real-time data analysis, predictive maintenance, and automated workflows. |
| **Responsiveness** | Enables quick responses to maintenance needs and operational challenges via remote monitoring and alerts. |
| **Transformation** | Transforms traditional manufacturing and supply chain practices by integrating smart technologies and connectivity. |

Examples found in D2.2:

- Sisteplant: Provides a Manufacturing Execution System (MES) with lot dashboards, predictive maintenance features, and remote work-order guidance.
- Impinj: Utilizes RAIN RFID technology for real-time location tracking of parts and efficient rerouting within the supply chain.

- Comau: Offers Iot-connected robotics equipped with self-diagnosis capabilities and a plug-and-play architecture for enhanced production flexibility.

**Adoption Barriers**

Despite its maturity, IoT adoption in the automotive ecosystem faces several challenges:

*Table 51: Adoption barriers for IoT in automotive.*

| Barrier | Explanation |
|---|---|
| **Integration Complexity** | Challenges in integrating IoT solutions with existing legacy systems can lead to operational inefficiencies and data silos. |
| **Workforce Training Gap** | There is a need for significant training to ensure that employees can effectively utilize IoT technologies and interpret the data generated. |
| **Data Security Concerns** | Risks associated with data breaches and unauthorized access to sensitive information can hinder IoT adoption. |
| **Legacy Equipment Compatibility** | Ensuring compatibility between new IoT devices and existing legacy equipment is often a significant challenge. |
| **Cybersecurity Needs** | Increased connectivity raises the necessity for robust cybersecurity measures to protect against potential threats. |

These barriers are consistent with those identified across ecosystems.

In conclusion, Internet of Things (IoT) offers **significant opportunities** to enhance resilience in the automotive sector by improving efficiency, visibility and responsiveness. IoT technologies enable organizations to make data-driven decisions and optimize their operations through applications such as predictive maintenance, real-time part tracking, and remote work-order guidance.

But there are challenges such as the complexity of integrating with legacy systems and the need for workforce training can prevent wider adoption. While the strategic potential of the IoT is recognized, its current impact is limited as organisations navigate these barriers. Ultimately, the IoT is set to transform the automotive landscape, but its full benefits have yet to be realized.

### 2.1.4.5 5G connectivity in automotive

**Maturity Level: Medium**

- Although 5G applications are being explored and implemented in pilot projects, full adoption is still developing. Integration is in its early stages.

**Impact Level: Strategic**

- It improves efficiency and real-time tracking. 5G is transforming automotive operations, but its impact is limited by high deployment costs and integration issues. Addressing these will make 5G a vital tool for the automotive sector.

**Applications in the automotive Sector**

5G technology is revolutionizing the automotive sector by enabling faster and more reliable communication. Key applications, as described in D2.2, include:

- **Seamless Data Exchange:** Enhances communication within automotive logistics for efficient data transfer.
- **Smart Factory Automation:** Utilizes 5G and AI for improved automation processes, increasing efficiency.
- **Private 5G Networks:** Optimizes engine production processes with dedicated, reliable connectivity.
- **Real-Time Supply Tracking:** Facilitates tracking of parts in real time, improving supply chain visibility.
- **AI Monitoring and Digitization:** Supports complete digitization of production lines through 5G-powered AI monitoring.
- **Network Slicing:** Allows tailored connectivity for specific logistics and automation needs.

These applications contribute to improved operational efficiency and real-time responsiveness in the automotive industry.

**Resilience Capabilities**

5G Technology contributes to several resilience dimensions:

*Table 52: Resilience capabilities for 5G in automotive.*

| Capability | Description |
|---|---|
| Redundancy | Provides consistent connectivity and backup options through advanced network slicing, ensuring uninterrupted operations. |
| Operational Efficiency | Enhances efficiency by enabling real-time data exchange and automation in logistics and production processes. |
| Resilience | Improves resilience by supporting rapid response and adaptability to disruptions through seamless communication. |
| Efficiency | Optimizes operational workflows and resource allocation, reducing latency and improving overall productivity. |
| Market Strength | Strengthens market position by facilitating advanced applications such as autonomous driving and smart factory automation. |

Examples found in D2.2:

- **Cellnex:** Provides shared infrastructure that enables real-time supply tracking, enhancing logistics efficiency.
- **Siemens:** Delivers 5G-powered AI monitoring solutions alongside full-line digitization to streamline production processes.
- **Nokia:** Offers network slicing technology to support AI-driven logistics and factory automation, optimizing resource use.

**Adaption Barriers**

Despite its growing maturity, 5G Technology adoption in the automotive ecosystem faces several challenges:

*Table 53: Adoption barriers for 5G in automotive.*

| Barrier | Explanation |
|---|---|
| **Multi-Country Rollout** | The challenge of implementing 5G infrastructure across multiple countries with varying regulations can complicate adoption. |
| **High Cost** | Significant investment is required for the deployment of 5G technology, which can be a barrier for many organizations. |
| **Legacy Systems** | Existing legacy systems may not be compatible with 5G technology, requiring substantial upgrades or replacements. |
| **Integration Issues in Traditional Plants** | Difficulty in integrating 5G solutions within established manufacturing processes and equipment can hinder operational efficiency. |

These barriers are consistent with those identified across ecosystems.

In conclusion, the opportunities 5G presents for enhancing resilience in the automotive sector are significant. 5G will improve operational efficiency, real-time data exchange and automation. Its applications will enable organisations to optimize processes and respond swiftly to disruptions.
The strategic potential of 5G is acknowledged, but its current impact remains limited as organisations work to address the barriers to its full implementation. While the potential is acknowledged, the impact is limited as organisations address the barriers. Ultimately, 5G is set to transform the automotive landscape.

### 2.1.4.6 Robotics in automotive

**Maturity Level: High**

- Robotics has been widely adopted in manufacturing to improve efficiency and quality. It is a well-established technology used by many organisations.

**Impact Level: Transformative**

- Robotics changes how the automotive industry operates by automating complex tasks, improving safety and enabling flexible manufacturing. It enhances operational capabilities and resilience by reducing labour dependency and streamlining workflows. The current impact is substantial, and advancements in robotics and AI will drive further innovation and efficiency.

**Applications in the automotive Sector**

Robotics technology is integral to enhancing efficiency and productivity within the automotive industry. Key applications, as described in D2.2, include:

- **Robotic Machining, Assembly, and Testin**g: Robots are utilized for precise machining, assembly, and testing of car engines and components, ensuring high quality and consistency.
- **Full Robotic Systems for Powertrain Manufacturing:** Implementing complete robotic systems streamlines the manufacturing and inspection processes for powertrains.

- **Custom Industrial Robots:** Tailored robots are deployed for specific tasks such as welding, painting, and assembly within automotive plants, allowing for greater flexibility in production.
- **AI-Enabled Robotic Production:** Integrating AI with robotic systems facilitates adaptable manufacturing processes that respond to varying production demands.
- **Precision Robotic Processes:** Employing robots for high-precision tasks reduces the need for labor and minimizes the risk of errors.
- **Robotic Automation for Safety:** Automating hazardous tasks improves workplace safety and helps alleviate operational bottlenecks, enhancing overall efficiency.

These applications enhance the resilience of the automotive sector by improving operational efficiency, safety, and adaptability to changing production conditions.

**Resilience Capabilities**

Robotics contributes to several resilience dimensions:

*Table 54: Resilience capabilities for robotics in automotive.*

| Capability | Description |
|---|---|
| **Operational Efficiency** | Enhances productivity by automating repetitive tasks, leading to faster production cycles and reduced labor costs. |
| **Market Strength** | Improves competitiveness by enabling advanced manufacturing processes and adapting to market changes quickly. |
| **Safety** | Increases workplace safety by automating hazardous tasks and reducing the risk of human error in critical operations. |
| **Efficiency** | Streamlines operations through precision robotic processes, minimizing waste and optimizing resource use. |

Examples found in D2.2:

- **Comau Robotics:** Offers AI-enabled robotic production systems that enhance flexibility in automotive manufacturing.
- **Fanuc Robotics:** Specializes in precision robotic processes designed to reduce labor demand in manufacturing operations.
- **Vuletech:** Focuses on robotic automation solutions that improve safety and minimize operational bottlenecks in production environments.

Despite its maturity, Robotics adoption in the automotive ecosystem faces several challenges:

*Table 55: Adoption barriers for robotics in automotive.*

| Barrier | Explanation |
|---|---|
| **High Setup Cost** | The initial investment required to implement robotic systems can be substantial, posing a barrier for many companies. |

| | |
|---|---|
| **Complex Customization** | Tailoring robotic solutions to meet specific production needs can be complicated and time-consuming. |
| **Expensive Maintenance** | Ongoing maintenance and servicing of robotic systems can incur high costs, impacting overall profitability. |
| **Skilled Workforce Needed** | A trained workforce is essential to operate and maintain advanced robotic systems, leading to potential skill gaps. |
| **Tech Integration Hurdles** | Integrating robotics with existing systems and processes can present significant challenges. |
| **Workforce Training Demands** | Extensive training is required to ensure employees can effectively work alongside robotics, which can take time and resources. |

These barriers are consistent with those identified across ecosystems.

In conclusion, robotics technology is **vital to the automotive industry**, enhancing efficiency and productivity. It includes robotic machining, assembly and testing, as well as robotic systems for manufacturing powertrains. Custom industrial robots are used for welding and painting, while AI-enabled robotic production facilitates flexible manufacturing processes. Robotic processes are precise, reduce labor demand and enhance safety and reduce operational bottlenecks.
Robotics is resilient, efficient, strong and safe, and contributes to a manufacturing environment that is adaptable and reliable. These capabilities contribute to a more adaptable and reliable manufacturing environment. Integration of technology and workforce training is essential to realize the potential of robotics in automotive applications. Robotics has significant potential to improve performance and resilience. Overcoming these challenges is essential for wider adoption.

#### 2.1.4.7 Edge computing in automotive

**Maturity Level: Medium**

- Edge Computing is proven and effective in various sectors, but not yet widely adopted in the automotive sector. It is still in the medium maturity level of deployment.

**Impact Level: Strategic**

- Edge Computing is significant as it enables functions in resilience and operations, such as real-time data processing and local decision-making. It is recognised as a foundational technology in the automotive sector.

**Applications in the automotive Sector**

According to D2.2, key applications of Edge Computing in the automotive sector include:

- **Distributed Edge Platforms:** Facilitate secure, real-time vehicle manufacturing through industrial edge data centers designed for factory automation and data processing.
- **Low-Latency Data Handling:** Enables quick and secure handling of factory data, supporting real-time production responsiveness.
- **On-Site Analytic**s: Supports localized analytics and IT processing close to production assets, enhancing decision-making at the source.

These applications emphasize the importance of Edge Computing in improving efficiency, security, and responsiveness in automotive manufacturing processes

**Resilience Capabilities**

Edge Computing contributes to several resilience dimensions:

*Table 56: Resilience capabilities for edge computing in automotive.*

| Capability | Description |
|---|---|
| **Adaptability** | Enables quick adjustments in production processes and systems based on real-time data insights, allowing for agile responses to changes. |
| **Efficiency** | Edge computing enhances operational efficiency by processing data locally, reducing latency, and optimizing bandwidth usage. |

Examples found in D2.2:

- **Cisco Systems**: They specialise in distributed edge platforms for secure, real-time vehicle manufacturing. Their solutions enhance operational efficiency and improve the overall manufacturing process.
- **Rittal**: It offers industrial edge data centres specifically designed for factory automation and data processing. Their systems support the secure, low-latency handling of factory data, enabling responsive production environments.

**Adoption Barriers**

Despite its maturity, Edge Computing adoption in the automotive ecosystem faces several challenges:

*Table 57: Adoption barriers for edge computing in automotive.*

| Barrier | Explanation |
|---|---|
| **High Implementation Cost** | The initial investment required for deploying edge computing solutions can be significant, which may deter organizations. |
| **Integration Complexity** | Difficulty in integrating edge computing with existing legacy systems can pose challenges and slow down adoption. |
| **Space Constraints** | Limited physical space in certain environments can restrict the deployment of additional edge computing infrastructure. |
| **Integration with Existing Systems** | Ensuring compatibility with current systems and software can complicate the adoption process and require additional resources. |

These barriers are consistent with those identified across ecosystems.

In conclusion, edge computing presents substantial opportunities for enhancing resilience within the automotive sector. By processing data closer to its source, it significantly improves operational efficiency and enables real-time decision-making, both of which are critical in a rapidly changing environment. Applications include distributed edge platforms

for secure vehicle manufacturing, industrial edge data centres for factory automation and localized processing to support real-time production responsiveness.
Despite its potential, the current impact of Edge Computing is limited due to several adoption barriers, including high implementation costs and integration complexities with existing systems. Organizations must overcome these challenges to fully realize the benefits of edge computing. Ultimately, as these barriers are addressed, Edge Computing is poised to play a transformative role in the automotive industry, enhancing adaptability, visibility and operational resilience.

### 2.1.4.8 Summary of digital maturity in automotive

*Table 58: Digital maturity in automotive.*

| Technology | Maturity | Impact | Key Applications | Resilience Capabilities | Adoption Barriers |
|---|---|---|---|---|---|
| **AI** | High | Transformative | Automatic driving integration, predictive maintenance, production optimization | Adaptability, Efficiency, Visibility | High implementation costs, integration complexity, need for specialized expertise, integration with existing CRM Systems |
| **Blockchain** | Medium | Strategic | Real-time part tracking, recall optimization, secure data ledger, supply chain monitoring, full component traceability, telematic security | Adaptability, Efficiency, Financial Strength, Transform, Visibility, Redundancy | Integration with Legacy Systems, Regulatory Uncertainty, Expertise Gap, Performance Bottlenecks, Customization Complexity, High Initial Investment, Compliance Certification, Legacy Integration Hurdles, |
| **Digital Twin** | Medium | Strategic | Operational Strategy Evaluation, Process Optimization, Predictive Maintenance, Virtual Training Environments, Immersive 3D Models | Adaptability, Efficiency, Visibility | Integration with Legacy Systems, Training Needs |
| **IoT** | Medium | Strategic | Predictive Maintenance, Real Time Part location, | Adaptability, Redundancy, Visibility, Efficiency, Responsiveness, | Integration Complexity, Workforce Training Gap, |

| | | | | | |
|---|---|---|---|---|---|
| | | | Remote Work-order Guidance, Connected robotics, Status tracking of components | Transformation | Data Security Concerns, Legacy Equipment Compatibility, Cybersecurity Needs |
| **5G** | Medium | Strategic | Seamless Data Exchange, Smart factory automation, Private 5G Networks, Real-time Supply tracking AI monitoring and digitization, Network slicing | Redundancy, Operational Efficiency, Resilience through rapid response, Efficiency Market Strength | Multi-Country Rollout, High Cost, Legacy Systems, Integration Issues in Traditional Plants |
| **Robotics** | High | Transformative | Robotic Machining, Assembly, and Testing, Full Robotic Systems for Powertrain Manufacturing, Custom Industrial Robots, AI-Enabled Robotic Production, Precision Robotic Processes, Robotic Automation for Safety | Operational Efficiency, Market Strength, Safety, Efficiency | High Setup Cost, Complex Customization, Expensive Maintenance, Skilled Workforce Needed, Tech Integration Hurdles, Workforce Training Demands |
| **Edge Computing** | Medium | Strategic | Distributed Edge Platforms Low-Latency Data Handling On-Site Analytics | Adaptability, Efficiency | High Implementation Cost, Integration Complexity, Space Constraints, Integration with Existing Systems |

## 2.2 Survey

To support the gap analysis presented in this deliverable, a dedicated "Maturity Analysis Survey: Mapping Technology Gaps in Industrial Ecosystems" was conducted using the EUSurvey platform between July 10 and August 8, 2025 (see Annex 1). The survey was designed by F6S and circulated to all participating clusters and Digital Innovation Hubs (DIHs) involved in the RISE-SME project. Its objective was to gather structured input from stakeholders across the textile, agri-food, digital, and automotive ecosystems regarding the adoption, maturity, and main barriers to key digital technologies.
The survey collected information on digital maturity levels, technology adoption (including AI, IoT, digital twins, blockchain, data spaces, 5G, edge computing, AR/VR, robotics, and 3D printing), as well as perceived gaps, drivers, and barriers within each ecosystem. Additional questions explored technology transfer needs, supplier landscapes, and criteria for selecting technology providers.

10 clusters or companies from the clusters responded to the survey. Their answers complement the desk research analysis, by providing the perception of technological gaps among the ecosystems' representatives, as well as highlighting priority areas for collaboration and capacity-building, and guide future activities under the RISE-SME project.

### 2.2.1 Digital ecosystem

The survey respondents from the digital ecosystem identified as the most widely used technologies: Artificial Intelligence, IoT and Edge Computing. The technology with the highest potential to increase resilience was found to be artificial intelligence.

Even though artificial intelligence and edge computing appear to be medium or highly used, desk research showed the high maturity of digital twins, and this was not perceived by the ecosystem representatives. The same applies to blockchain, with a medium maturity level, where the survey respondents indicate that, to their knowledge, it is currently not in use.

These findings highlight partial alignment between perceived and actual technological maturity, and underscores the need for better awareness, training, and strategic investment to fully leverage digital technologies for resilience.

The barriers for implementation identified by the clusters were the unclear return on investment (ROI) and the lack of digital skills.

### 2.2.2 Agri-food ecosystem

The survey responses from the agrifood ecosystem were aligned with the desk research results shown above. They also identified robotics as a key technology for their sector.

They identified as barriers to implementation data privacy or security concerns, as well as unclear return on investment (ROI) and lack of digital skills & resistance to change.

The survey yields the conclusion that the agrifood respondents are aware of and aligned with technology maturity levels in their ecosystem.

It also highlights that successful technology implementation requires addressing trust, training, and transformation—ensuring that digital solutions are secure, economically justified, and supported by a skilled and receptive workforce.

### 2.2.3 Textile ecosystem

The survey responses from the textile ecosystem were aligned with the desk research results shown above. On top of the presented technologies above, they also indicated that 5G was widely used in their ecosystem.

As shown in previous ecosystems, they also identified artificial intelligence as the technology with the highest potential to increase resilience.

On top of the barriers mentioned in previous ecosystems, respondents from the textile sector indicated that regulatory or compliance constraint, lack of awareness of available solutions and dependence on critical technology suppliers were hindering technology adoption.

These results show that the textile ecosystem is increasingly embracing advanced technologies, including newer enablers like 5G. However, regulatory complexity, limited awareness, and supplier dependency are significant hurdles that must be addressed to unlock the full potential of digital transformation.

Targeted outreach, education, and policy support will be essential to overcome these barriers and foster a more resilient and digitally empowered textile ecosystem.

### 2.2.4 Automotive ecosystem

The responses from the automotive ecosystem confirmed the conclusions of the desk research.

They also identified artificial intelligence as the technology with the highest potential to increase resilience. This showcases how the automotive sector is technologically aligned with broader industry trends, particularly in recognizing the value of AI.

The main barriers for implementation were in line with all the other ecosystems, i.e. high investment or implementation cost, lack of digital skills and skills shortage and resistance to change. Addressing these challenges will require targeted investment support, workforce development programs, and change management strategies to foster a more adaptive and resilient ecosystem.

## 2.3 Heat map

This section synthesizes the results of a cross-ecosystem analysis on the implementation of digital technologies. Drawing from the analysis performed for the selected ecosystems, this heat map identifies the ecosystem where each technology demonstrates its highest level of maturity and impact. In other words, the heat map shows the most advanced and relevant use cases from the analysis performed per ecosystem supported by the main findings on key applications, resilience capabilities and barriers to adoption.
Each technology is represented according to its maturity level (Low, Medium and High), its impact (Transformative, Strategic, Niche) and its contribution to enhancing supply chain resilience. The objective is to highlight where the technologies are being used and what enables their implementation and what barriers remain.

*Table 59: Digital technologies heat map.*

| Technology | Ecosystem | Maturity | Impact | Key Applications | Resilience Capabilities | Adoption Barriers |
|---|---|---|---|---|---|---|
| AI | Digital | High | Transformative | On-demand mobility, route planning, autonomous vehicles, user behavior prediction | Adaptability, Efficiency, Visibility, Responsiveness | Integration complexity, data privacy, public acceptance |
| Digital Twin | Digital | High | Strategic | Mobility simulation, infrastructure planning, scenario testing | Adaptability, Efficiency, Visibility | Standardization, workforce training, legacy integration |
| Blockchain | Digital | Medium | Strategic | Decentralized identity, secure payments, smart contracts | Visibility, Efficiency, Security, Adaptability, Respond, Market strength, Transform, Financial strength | Interoperability, regulation, digital literacy, investment, industry standards, data privacy, integration, customization, complexity, user adoption reluctance |
| Data Spaces | Digital | Medium | Strategic | Federated data sharing, real-time coordination, data sovereignty | Visibility, Adaptability, Efficiency | Governance, standard adoption, integration, awareness |
| 5G Connectivity | Digital | High | Transformative | V2X communication, real-time data | Efficiency, Redundancy, | Infrastructure cost, regulation, |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | exchange, network slicing | Security, Market strength | cybersecurity, integration |
| Edge Computing | Digital | Medium | Strategic | Local data processing, real-time analytics, autonomous control | Efficiency, Visibility, Adaptability | Deployment complexity, integration, customization, interoperability |
| AR/VR | Digital | Medium | Strategic | AR navigation, immersive training, user engagement | Adaptability, Visibility, Efficiency, Market Strength, Transform | Hardware cost, user adoption, privacy, integration, regulation |
| IoT | Agrifood | Medium | Strategic | Input automation, irrigation control, condition monitoring, logistics tracking | Efficiency, Visibility, Respond, Adaptability | Connectivity, CAPEX, cybersecurity, maintenance network complexity |
| 3D Printing | Agrifood | Medium | Strategic | Spare parts for machines, food-safe tooling, custom packaging | Adaptability, Compliance, Customization, Visibility | High cost, material compatibility, certification needs, tech knowledge |
| Robotics | Automotive | High | Transformative | Robotic Machining, Assembly, and Testing, Full Robotic Systems for Powertrain Manufacturing, Custom Industrial Robots, AI-Enabled Robotic Production, Precision Robotic Processes, Robotic Automation for Safety | Operational Efficiency, Market Strength, Safety, Efficiency | High Setup Cost, Complex Customization, Expensive Maintenance, Skilled Workforce Needed, Tech Integration Hurdles, Workforce Training Demands |

The heatmap reveals the highest technological maturity within the digital ecosystem. Particularly, AI, Digital Twin and 5G Connectivity, show high maturity and transformative impact driven by applications such as autonomous mobility, infrastructure simulation, and real-time data exchange. Their contribution to resilience according to their capabilities (adaptability, visibility, and responsiveness) are aligned with the dynamic demands of digital mobility applications.

Blockchain and Data Spaces, although present across ecosystems, remain at a medium level of maturity. Their strategic value is evident, especially in secure data sharing and traceability, but widespread implementation is hindered by adoption barriers: interoperability, regulatory uncertainty, and legacy system integration. These challenges are not unique to one ecosystem, they are pervasive across sectors, suggesting a broader structural issue.

Interestingly, IoT and 3D Printing technologies find their strongest presence in the agrifood ecosystem. Applications, as irrigation control and custom packaging, are practical, targeted, and often incremental. They offer significant improvements in efficiency and adaptability, making them strategic for the sector. In this case, the innovation is grounded, gradual and deeply routed in the operational reality of the ecosystem.

Robotics stands out in the automotive ecosystem, with a high maturity level and transformative impact. This sector benefits from well defined industrial processes and capacity investment, which has facilitated the integration of advanced robotic. However, adoption barriers like cost, customization, and workforce retraining remain significant and need be addressed to scale further.

As can be observed, the table not only rank the technologies but also highlights the contextual advancement, specific achievements and ongoing challenges. Technologies evolve according to the ecosystems and are shaped by them, adapting the implemented applications to solve specific problems in the sectors and infrastructure the need to integrate with.

Moreover, the heatmap highlights the importance of tailoring digital technologies to the ecosystem circumstances. While some technologies have accomplished great advances in high-tech environments, others find their strengths in more conventional contexts. This diversity can be seen as a weakness, but it is a reflection of the multifaceted nature of resilience.

In conclusion, the heatmap illustrates where the advancement of digital technologies is occurring, where it is stuck, and where to go next.

# 3 Matchmaking tool

As part of Task 3.1, the project is developing a dedicated matchmaking tool to facilitate collaboration and technology transfer between traditional and tech-savvy SMEs across the textile, agri-food, digital, and automotive ecosystems. The tool will take the form of a user-friendly, web-based service hosted on the RISE-SME project website.

The matchmaking tool will offer a curated, searchable catalogue of technology needs ("Looking for") and offers ("Offering"), drawn from survey and interview data collected throughout the project. Users will be able to filter entries by ecosystem, technology area (e.g., AI, IoT, Blockchain, Digital Twin, Robotics, 3D Printing, etc.), type (need/offer), and maturity level. Additional keyword search functionality will help users quickly identify relevant opportunities.

Each entry in the catalogue will include a short description, the relevant ecosystem, the technology focus, maturity, and contact details. Where available, organisation logos or images will be included to enhance visibility. The tool will also feature options to download the full catalogue as a PDF or Excel file for offline use.

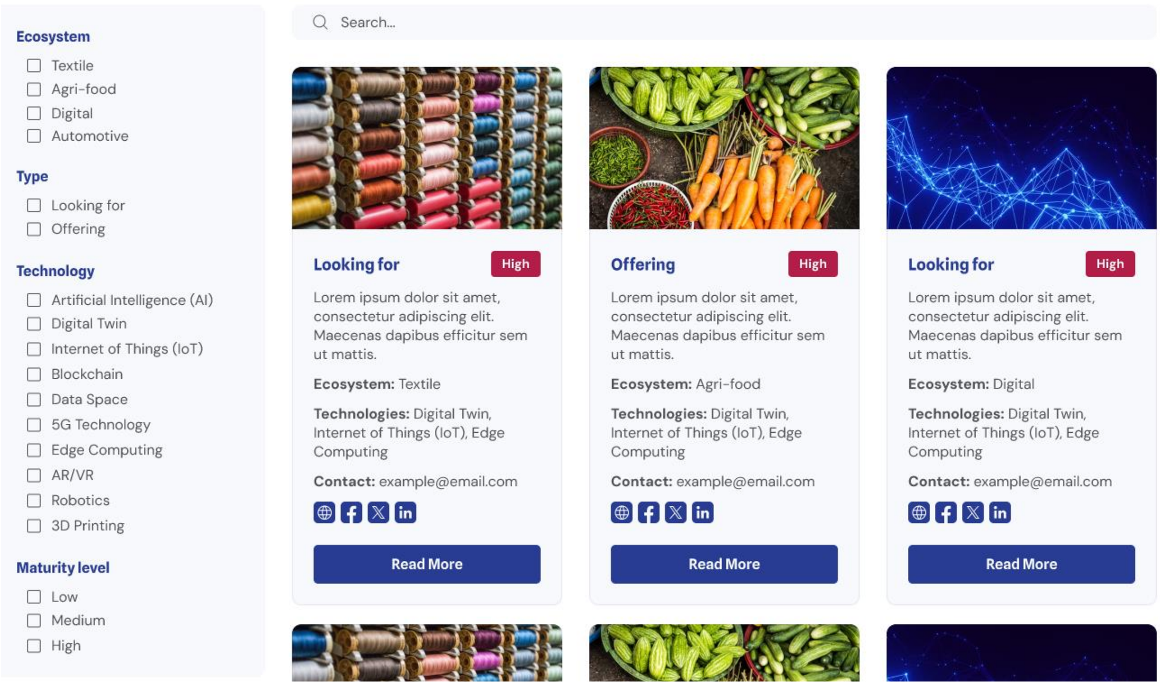


*Figure 1 Matchmaking tool filtering system and cards*

To further support ecosystem collaboration, the matchmaking tool will include information on upcoming matchmaking events and workshops, and offer users the option to register interest or request more information. The tool is designed for maximum accessibility, requiring no user accounts, and will be maintained and updated manually throughout the project's active phase, ensuring it remains a current and practical resource for SMEs and technology providers alike.

# 4 Gap analysis

## 4.1 Digital ecosystem: MaaS application

The implementation of digital technologies in MaaS demonstrates a promising correlation with various essential factors. Nonetheless, the assessment uncovers significant deficiencies where resilience capabilities are either underexploited or where some crucial elements remain inadequately addressed.

The incorporation of digital technologies in Mobility as a Service (MaaS) has facilitated substantial advancements in tackling several critical factors. Innovations such as **Artificial Intelligence (AI)**, **Blockchain**, **Digital Twin**, **Data Spaces**, **5G**, **Edge Computing**, and **Augmented Reality/Virtual Reality (AR/VR)** have been utilized to bolster resilience capabilities, including adaptability, efficiency, visibility, redundancy, market and financial strength, responsiveness, and transformation. However, the evaluation indicates that their complete potential has not yet been achieved.

A clear gap is evident in the distribution of these technologies across the critical factors. The **Technological disruptions and low digital maturity** critical factor is addressed by nearly all technologies, indicating a strong digital transformation already achieved. Similarly, **global and complex supply chains** critical factor is broadly addressed by technologies like **Digital Twin**, **Edge Computing**, and **5G**. This provides a significant improvement in **visibility** and **efficiency** for MaaS applications.

On the other hand, several critical factors remain underrepresented. **Environmental crises and natural disasters** critical factor is only indirectly addressed, with limited application of resilience capabilities such as **adaptability** and **redundancy**. **Waste management** is another area where the implementation of digital technologies is minimal, relying primarily on **efficiency** without leveraging **visibility** or **transform** capabilities that could drive sustainable practices. The **shortage of skilled labor** also stands out as a major barrier that has not been adequately addressed, despite the availability of technologies offering **transform** and **financial strength**.

Furthermore, the resilience capabilities embedded in these technologies are not always strategically aligned with the needs of the critical factors. Resilience capabilities like **transform** and **financial strength**, present in Blockchain and AR/VR, are not being fully utilized to support **business model innovation** or **workforce development**. **Political conflicts and crises** critical factor, while partially addressed through Blockchain's **adaptability** and **security**, lack of solutions that incorporate **redundancy** and **transformative** capabilities. Similarly, **infrastructure disruptions** critical factor, although targeted by Edge Computing and 5G, is not benefiting from **visibility** and **responsiveness capabilities** provided by digital technologies.

Finally, there is a **redundancy in technology deployment**. Certain technologies are repeatedly applied to the same critical factor, for example, **Digital Twin** and **Edge Computing** for **supply chain decentralization**, which may indicate an over-reliance on specific solutions while missing others that could offer complementary capabilities.

## 4.2 Agri-food ecosystem

The agrifood ecosystem, with the focus on the wine sector in this case, is advancing incrementally in the implementation of digital technologies but this progress is not as accelerated as other ecosystems. This sector is deeply traditional and therefore taking trends carefully and ensuring every step. While this is a key characteristic of the sector itself it results in the underutilization of available digital technologies and in the sector laging behind in digital transformation.

In the positive aspects, technologies such as **AI, IoT and blockchain** are already demonstrating significant potential. AI is existing with crop **forecasting** and **predictive maintenance**. The IoT is automating irrigation process and enhancing **visibility** in logistics. Blockchain offers **traceability** and **transparency**. These applications are already producing an effective change in the way the sector used to work.

Despite this, the implementation of the digital technologies in the ecosystem remains inconsistent. Some resilience capacities are well addressed like **efficiency and visibility**. However, other resilience capabilities have not been addressed by digital applications, this is the case of **redundancy, financial robustness, and transformative capacity**.

This presents a change. The agrifood ecosystem is highly susceptible to climate fluctuations, supply chain interruptions and market instability. Having alternative sourcing strategies, for example, should be a priority in this case. Yet the digital technologies that can provide this are not being consistently applied, such as **blockchain** for dynamic supplier mapping or **IoT** for real risk notifications.

**Strategic transformation** is also an important gap detected. Most digital technologies are used to improve existing operations not to redesign them in a more efficient way. Key implementations, able to enable SMEs to navigate uncertainty and maintain sustainable and productive operations, are not represented. Instruments supporting innovative business models, collaborative platforms or financial forecasting are not applied in the sector.

Additionally, there is a lack of **skills and digital literacy** in the ecosystem. SMEs in the sector are not ready for digital transformation and will encounter difficulties due the complexity of digital tools. Even in the case a technology is available it may not be user friendly. Initial investment, integration and lack of training are important challenges int he sector. Also, the connectivity gaps in rural regions must be addressed in this context making real-time data sharing an important logistics challenge.

## 4.3 Textile ecosystem

The comparison between the critical factors of the textile ecosystem and the applications of digital technologies helps to understand how the currently available technological solutions address, or fail to address, the main challenges faced by small and medium-sized enterprises (SMEs) in the sector.

Key critical factors include the **recurrent shortage of skilled labour, high operational costs, lack of transparency and traceability throughout the production chain, resource waste, and low adaptability to disruptions.** These elements directly compromise the resilience of the textile sector, particularly in the dimensions of **adaptability, visibility, efficiency, and market strength.**

However, there are emerging digital applications aimed at improving different resilience capabilities within the sector. Technologies such **as automated systems for cutting, sewing, and handling** offer solutions to increase operational efficiency and reduce waste, mitigating the impacts of high production costs and labour shortages. **Tracking platforms with RFID/BLE sensors** significantly enhance process visibility and traceability, contributing to more precise and sustainable resource management along the value chain. Furthermore, the use of **IoT platforms** with edge analytics enables real-time monitoring of machine health and the generation of alerts for predictive maintenance, supporting operational continuity and reducing the risk of unexpected shutdowns. AI-based technologies are also being used for demand forecasting and quality control, promoting greater adaptability and agile responses to market fluctuations.

Despite these significant contributions, the analysis reveals important gaps. For example, workforce qualification is identified as a critical factor but is not directly addressed by the highlighted technological solutions. On the contrary, the introduction of these technologies may, in many cases, exacerbate the exclusion of low-skilled workers unless implemented alongside retraining and technical capacity-building policies. Similarly, the strategic dimension of resilience, which involves broader capabilities such as organizational adaptation, market intelligence, and business model transformation, remains underdeveloped in the digital applications analyzed, which mostly focus on operational responses.

Thus, the digital technologies currently available demonstrate high potential to address a significant portion of the textile ecosystem's critical factors, especially in the dimensions of **efficiency, visibility, and response.** However, structural challenges related to workforce qualification and the strategic transformation of organizations still require more integrated and complementary approaches. Overcoming these challenges requires not only the adoption of advanced technologies but also their articulation with innovation support policies, professional training, and change management, in order to promote more resilient, sustainable, and disruption-prepared production chains.

Therefore, despite the broad potential of digital technologies to foster supply chain resilience, important gaps persist in the full utilization of these capabilities within the textile ecosystem.

The most frequently applied technologies in the sector, such as Artificial Intelligence (AI), Internet of Things (IoT), blockchain, augmented reality (AR/VR), robotics, and 3D printing, contribute significantly to strengthening certain capabilities, such as adaptability (through AI for demand forecasting), visibility (with IoT sensors and blockchain for traceability), and operational efficiency (via robotics and additive manufacturing). However, notable gaps remain in the development of redundancy, financial strength, and especially market strength capabilities.

Redundancy, essential to mitigate disruption risks, requires practices such as multiple suppliers, safety stock, and alternative logistics routes. While some IoT and blockchain solutions support traceability and monitoring, the adoption of technologies specifically aimed at building structural redundancies is limited in the sector. This may relate to the high costs and low digitalization among textile SMEs, which face significant barriers to implementing complex technologies.

Market strength, in turn, depends on stable relationships with customers and suppliers, as well as negotiation capacity. This dimension is scarcely represented in the currently applied technologies. The use of digital platforms that foster supply chain collaboration, for instance, is still incipient in the sector, limiting the development of this strategic capability.

Lastly, financial strength, the capacity to absorb economic shocks and invest in recovery, is not directly addressed by the mapped technologies. The absence of digital solutions focused on integrated financial management of the supply chain or predictive analysis of financial risks represents a significant gap, especially for SMEs, which are more vulnerable to economic instability.

Thus, overcoming these gaps requires a more holistic approach that combines technological innovation with capacity-building, financing, and inter-organizational collaboration policies tailored specifically to the needs and limitations of the textile sector.

## 4.4 Automotive ecosystem

The implementation of digital technologies in the automotive sector demonstrates significant advancements as it is a historically high-tech sector which acts as a technological and digital pioneer. However, the assessment reveals notable gaps where resilience capabilities remain underutilized or where certain critical factors are inadequately addressed by current technological applications. The integration of digital technologies in the electric vehicle production ecosystem has enabled substantial progress in tackling key critical factors, particularly those related to supply chain visibility and operational efficiency. Nevertheless, significant deficiencies persist in areas where resilience capabilities are either underexploited or where critical challenges remain technologically unaddressed. Furthermore, the industry is extremely OEM-dirven. That means that the sector's technology adoption patterns are heavily influenced by its OEM-driven structure, where original equipment manufacturers dictate technological choices throughout the supply chain. This hierarchical approach, while ensuring standardization and quality control, can constrain innovation and limit the adoption of resilience-enhancing technologies that may not align with OEM priorities. The concentration of decision-making power among a limited number of major automotive manufacturers may create dependencies that reduce overall supply chain resilience

The gap analysis reveals that certain high-risk critical factors identified in D1.2 receive limited support from current digital technology deployments. Political conflicts and crises, which ranked fourth in the automotive sector's risk assessment with significant impact potential, lack comprehensive technological responses. While the sector has developed strong visibility and efficiency capabilities through advanced analytics and B2B digital platforms, these technologies provide minimal protection against geopolitical disruptions that can fundamentally alter supply chain access and market dynamics. Infrastructure and logistics disruptions also reveal technological gaps despite the sector's strong focus on efficiency capabilities. While once again B2B digital platforms facilitate communication and coordination, the lack of comprehensive (collaborative supply chain) digital twin implementations and limited deployment of IoT for real-time infrastructure monitoring constrains the sector's ability to anticipate and respond to logistics network failures. Redundancy capabilities face technological limitations as well. While the sector recognizes the importance of alternative suppliers and backup systems, current digital implementations provide insufficient support for dynamic redundancy management, supplier network optimization, or automated failover mechanisms during supply chain disruptions.

The automotive sector's technology deployment reveals a concentration on mature, proven solutions rather than innovative combinations that could provide synergistic benefits. The focus on advanced analytics and robotics, while valuable for operational efficiency, creates an imbalanced technological portfolio that may limit resilience potential. The underutilization of blockchain for supply chain transparency to tacke supply chain complexity (rank two in risk assessment from D1.2) and traceability, combined with minimal deployment of digital twins for scenario planning, represents missed opportunities for enhanced visibility and adaptability capabilities. The sector's conservative approach to emerging technologies, as noted in D2.2, particularly regarding generative AI and comprehensive digital twin implementations (especially in SMEs, not for the OEMs), may limit its ability to address complex, interconnected supply chain challenges that require advanced predictive and adaptive capabilities.

# 5 Recommendations and outlook

## 5.1 Digital ecosystem: MaaS application

To fully unlock the potential of digital technologies in MaaS and address the uncovered critical factors, several recommendations are proposed.

In the first place, it is essential to **use of underutilized resilience capabilities** provided by digital technologies. Technologies that provide **transform** and **financial strength**, such as Blockchain and AR/VR, can facilitate the **evolution of business models** and the **development of digital skills** within traditional SMEs.

Second, attention should be directed toward **critical factors that have received limited technological support**. The **Environmental crises and natural disasters** critical factor could benefit from **predictive analytics** and **simulation tools** provided by AI and AR/VR, enabling proactive risk management. The **Waste management** critical factor could benefit from technologies that enhance **visibility** and **transform**, such as **Data Spaces** and **AR/VR**, to optimize resource use and reduce inefficiencies. To address the **Skills gaps** critical factor, a combination of **AR/VR** (i.e. immersive training) and **Blockchain** (secure credentials) can improve workforce resilience.

Third, a more **balanced deployment of technologies** is needed. Rather than clustering multiple solutions around a few factors, as highlighted in the previous section, a **redistribution of technological applications** to ensure a complete resilience strategy is necessary. This includes **combining technologies** to create synergistic effects. For example, **AI**, **Blockchain**, and **Digital Twin** can **increase security and transparency** in MaaS. Similarly, combining **Edge Computing** with **5G** can enhance **real-time responsiveness** and **redundancy**.

Finally, promoting the **adoption of digital technologies in traditional SMEs** is crucial. One simple way to bring digital technologies into SMEs is by starting with the ones that are easy to implement, especially for the less experienced ones, like **Data Spaces** and **AR/VR,** which can offer **visibility** and **adaptability** without requiring high levels of digital maturity.

In conclusion, digital technologies have made significant contributions to MaaS, but their deployment remains uneven and incomplete. A strategic alignment between resilience capabilities and critical factors that promote a more integrated and inclusive technological approach can unlock the full potential of digital technologies in MaaS.

*Table 60: Gaps and recommendations identified for the Digital Ecosystem*

| Main Gaps Identified | Recommendations |
|---|---|
| **Underrepresentation of critical factors** such as *environmental crises*, *waste management*, and *skills gaps*. | Target these factors with technologies offering **predictive analytics**, **simulation**, and **training capabilities** (e.g., AI, AR/VR, Blockchain). |
| **Underutilization of resilience capabilities** like *transform*, *financial strength*, and *market strength*. | Leverage technologies such as **Blockchain** and **AR/VR** to support **business model innovation**, **workforce development**, and **supplier diversification**. |
| **Redundancy in technology deployment**, with multiple technologies applied to the same factor (e.g., supply chain decentralization). | Redistribute technological applications to ensure **balanced coverage** across all critical factors and avoid over-reliance on specific solutions. |
| **Limited integration of complementary technologies** to create synergistic effects. | Combine technologies (e.g., **AI + Blockchain + Digital Twin**, **Edge Computing + 5G**) to enhance **adaptability**, **security**, and **real-time responsiveness**. |

## 5.2 Agri-food ecosystem

The agrifood ecosystem is making curious progress in digital transformation. The ecosystem is very traditional, and the changes are slow and deliberate. But this makes the agrifood ecosystem lag behind other industries in terms of resilience. But resilience is a necessity in the current changing and unstable environment that needs to be unlocked to keep the sector competitive and in good shape.

Some solid steps forward have been made. Technologies like **AI, IoT and blockchain** are already making a difference in the ecosystem. AI supports farmers in forecasting demand and optimizing resources. IoT is used for automating irrigation and improving logistics. Blockchain brought traceability and transparency to the supply chain.

However, the reality is that digital technologies implementation in the ecosystem is inconsistent. Aspects like **redundancy, financial stability and strategic transformation** are not sufficiently addressed. Additionally, the need for investment, **technology integration and lack of training** are challenges slowing down the technological transformation of the sector. Moreover, c**onnectivity challenges** in rural areas complicate real-time data sharing.

To even the digital transformation in the agrifood ecosystem, technological **accessibility** must be addressed. This implies creating modular, cost-effective solutions that farmers can easily implement without complicated technical knowledge. Plug and play IoT kits, simplified dashboards and collaborative data spaces designed with SMEs requirements.

**Skills and trust** in the sector also must be addressed. Training initiatives, digital literacy programs and supporting services should accompany digital tools to secure an effective and long-lasting deployment.

Technologies, such as **AI and blockchain**, are underutilized according to their capacity. These technologies are applied to optimize operations while they have the potential of enabling dynamic sourcing, risk assessment, and scenario planning. **Blockchain** could be used to map suppliers and monitor compliance in real time while **digital twins** could model disruptions.

Lastly, solutions must be **connected and integrated**. Combining **AI with IoT or blockchain with data spaces** can generate synergies to enhance the resilience capacity of agrifood.

In summary, the agrifood ecosystem has the digital tools required to boost its digital transformation, but these isolated elements need to be connected, integrated, and inclusive in a more collaborative and strategic approach.

*Table 61: Gaps and recommendations identified for the Agrifood Ecosystem*

| Main Gaps Identified | Recommendations |
|---|---|
| **Limited deployment of resilience capabilities** such as *redundancy*, *financial robustness*, and *transformative capacity*. | Promote the use of **Blockchain** and **AI** for **dynamic sourcing**, **risk profiling**, and **scenario planning**. Encourage **digital twins** for disruption simulation and contingency testing. |
| **Technologies used mainly for operational improvement**, not strategic transformation. | Support the development of **collaborative platforms**, **financial forecasting tools**, and **business model innovation** strategies tailored to SMEs. |
| **Barriers to adoption** due to cost, complexity, and lack of skills. | Develop **modular, low-cost solutions**. Launch **training programs**, **digital literacy initiatives**, and **support networks** to ease adoption. |
| **Connectivity gaps in rural areas** hinder real-time data sharing. | Invest in **rural digital infrastructure** and promote **offline-capable solutions** that sync when connectivity is available. |
| **Fragmented use of complementary technologies (e.g., AI, IoT, Blockchain).** | Encourage **technology bundling** (e.g., **AI + IoT**, **Blockchain + Data Spaces**) to enhance **visibility**, **adaptability**, and **efficiency**. |

## 5.3 Textile ecosystem

The textile sector, particularly among small and medium-sized enterprises (SMEs), faces persistent challenges that compromise supply chain resilience. Key issues include a shortage of skilled labour, high operational costs, limited transparency and traceability, resource inefficiencies, and low adaptability to disruptions. While emerging digital technologies offer promising solutions, critical gaps remain in their application and integration.

The previous analysis has shown how advanced technologies such as Artificial Intelligence (AI), Internet of Things (IoT), robotics, blockchain, and 3D printing are increasingly used to enhance operational efficiency, visibility and traceability and adaptability.

Despite these advancements, several capabilities remain underdeveloped, such as redundancy – with limited adoption of tools for supplier diversification and alternative logistics, market strength – with weak integration of platforms that foster supply chain collaboration and negotiation capacity, or financial strength – with absence of digital tools for financial risk management and investment planning.

All of the above needs to be encompassed with fostering workers skills. Indeed, in line with Industry 5.0, resilient supply chains should be human-centric. Artificial intelligence, the technology with most potential impact in the textile ecosystem, will allow radical workplace innovation, with the human-machine interactions at its core. These supply chains 5.0 would empower workers and ultimately yield more resilient supply chains.

*Table 62: Gaps and recommendations identified for the Textile Ecosystem*

| Main Gaps Identified | Recommendations |
|---|---|
| Technologies are not addressing the **shortage of skilled labour** and may exclude low-skilled workers. | Develop sector-specific training to upskill workers in digital tools (e.g., AI, IoT, robotics).<br>Promote inclusive digital transformation by integrating human-centric design in technology deployment, in line with the Industry 5.0.<br>Create public-private partnerships to fund reskilling initiatives, especially targeting SMEs. |
| Lack of digital tools supporting **market and financial strength capabilities**. | Implement digital twins to model business scenarios and test strategic decisions under different disruption conditions.<br>Adopt AI-driven market intelligence tools to analyse trends, enabling agile business model adaptation.<br>Introduce AI-based financial forecasting tools to simulate economic scenarios and guide investment decisions. |
| Limited use of technologies to support **redundancy** (e.g., alternative suppliers) | Use blockchain and IoT for supplier mapping and risk profiling, enabling dynamic sourcing and contingency planning.<br>Develop collaborative platforms for supplier diversification and shared logistics, reducing dependency on single sources. |

| | |
|---|---|
| | Incentivize SMEs to incorporate reconfigurability in their systems to respond quickly to disruptions. |
| **Fragmented approaches** to technology adoption and resilience-building | Design ecosystem-wide innovation roadmaps that align technology deployment with resilience goals.<br>Foster textile-specific digital innovation hubs to support experimentation, prototyping, and knowledge exchange. |

## 5.4 Automotive ecosystem

The automotive ecosystem is one of the most advanced in implementing digital technologies. **Robotics**, **artificial intelligence** and **digital twins** are already integrated into manufacturing operations, and the sector keeps working towards digital transformation. However, when considering the resilience achieved, the progress made by the sector is not so powerful. Upon closer examination, it is evident that several critical factors in the ecosystem, such as **geopolitical uncertainties**, **infrastructure interruptions** and **supply chain complexities**, remain unaddressed by existing digital applications.

One of the main obstacles found is the **OEM centric framework** of automation. A centralized decision-making causes slow innovation transfer to SMEs. This situation creates a bottleneck for technologies aimed at enhancing resilience that do not align with the priorities of OEMs. In consequence, although automation has a high performance in technological proficiency, it lacks **agility** or **inclusiveness**.

Additionally, technologies such as **blockchain** and **digital twins**, which could provide significant advantages for **traceability** and **scenario analysis** are underutilized. While **IoT** and **5G** are progressing, their **integration** often remains limited to isolated applications, leaving broader supply chain coordination and redundancy capabilities undeveloped.

According to this, several measures can be implemented. Firstly, it is important to dismantle existing silos. Digital technologies should not only focus on operational efficiency and process improvement, but they also need to be **implemented strategically to bolster resilience**. **Blockchain** can be used beyond traceability to include dynamic **supplier mapping** and **risk assessment**. **Digital twins** can be expanded from SEMs to SMEs, helping **simulate disruptions** and assess **contingency plans**.

Secondly, to address **redundancy**, automotive must invest in applications that facilitate **alternative sourcing**, **failover strategies** and multi-tier supplier **visibility**. At present, redundancy is not a resilience capability achieved by digital technologies.

Thirdly, the **accessibility** of digital technologies is crucial. SMEs should have access to **lightweight, modular solutions** that do not necessitate considerable investment or extensive technical know-how. Consider plug-and-play IoT kits, simplified edge computing platforms, and collaborative data environments designed to cater to the needs of SMEs.

Lastly, the **human element** needs to be addressed. Workforce training, change management and digital literacy are key elements to improve resilience through sigital technologies.

*Table 63: Gaps and recommendations identified for the Automotive Ecosystem*

| Main Gaps Identified | Recommendations |
|---|---|
| **Underrepresentation of critical factors** such as *geopolitical risks*, *infrastructure disruptions*, and *supply chain complexity*. | Expand the use of **blockchain** and **digital twins** for **scenario planning**, **traceability**, and **supplier risk profiling**. Promote **IoT** and **5G** for real-time infrastructure monitoring and logistics coordination. |
| **OEM-driven adoption limits innovation** and slows down SME integration. | Encourage **technology decentralization** by supporting SME-specific solutions and platforms. Develop **collaborative innovation frameworks that include SMEs in technology planning and deployment.** |
| **Limited deployment of redundancy capabilities** across the supply chain. | Invest in digital tools for **supplier diversification**, **failover planning**, and **multi-tier visibility**. Use **blockchain** and **IoT** to enable dynamic sourcing and contingency management. |
| **Fragmented use of complementary technologies** (e.g., AI, robotics, edge computing). | Promote **technology bundling** strategies (e.g., **AI + robotics + edge computing**) to enhance **adaptability**, **efficiency**, and **real-time responsiveness**. |
| **Barriers to SME adoption** due to cost, complexity, and lack of skills. | Develop **modular, low-cost solutions** tailored to SMEs. Provide **training programs**, **digital literacy initiatives**, and **financial incentives** to support adoption. |

# 6 Conclusions

The adoption of digital technologies across industrial ecosystems is uneven. While some sectors have embraced digitalization extensively, others remain underdeveloped due to ecosystem limitations or uncertainty. Indeed, this deliverable has explored this disparity by identifying technological gaps between digitally advanced and more traditional ecosystems (and its SMEs). This has helped uncover opportunities for collaboration, knowledge transfer, and inclusive digital transformation across all ecosystems.

On the one hand, common gaps across ecosystems have been identified. Indeed, underutilization of resilience capabilities like financial strength have been pinpointed by all ecosystems. Moreover, all ecosystems claim the limited deployment of redundancy capabilities across the supply chain. Additionally, the fragmented use of complementary technologies (e.g., AI, robotics, edge computing) is also identified as a main gap. All ecosystems agree as well on the main barriers to SME adoption, i.e., cost, complexity, and lack of skills.

On the other hand, some ecosystems identify specific gaps tailored to their own challenges. For instance, the agrifood sector faces connectivity gaps in rural areas hindering real-time data sharing, whereas in the automotive ecosystem, OEM-driven adoption limits innovation and slows down SME integration.

To solve general gaps, this document proposes recommendations to be implemented across ecosystems, such as the combination of technologies or the development of modular and low-cost solutions for SMEs. This is supported by collaborative frameworks for SMEs innovation, as well as by training programs and digital literacy initiatives.

Other recommendations were developed targeting a specific ecosystem, but have transferability potential to be implemented in other ones. Such recommendations include designing ecosystem-wide innovation roadmaps that align technology deployment with resilience goals, or fostering digital innovation hubs to support experimentation, prototyping, and knowledge exchange.

This transferability path will be further explored during the lifetime of RISE-SME project. In order to encourage traditional SMEs to adopt advanced technologies, a pilot implementation plan will be created, demonstrating how to integrate advanced technologies into supply chain processes in each ecosystem. It will be built upon the results of a Business Model Game (BMG) selected by the ecosystems' actors. RISE-SME will define new collaboration mechanisms, following a joint strategy for networking and stakeholder involvement, leveraging RISE-SME network as well as reaching out to identified technology suppliers.

# 7 Annex 1

**Maturity Analysis Survey: Mapping Technology Gaps in Industrial Ecosystems**

*https://ec.europa.eu/eusurvey/runner/677fbc65-671b-2072-b8fe-567b08054395*

RISE SME website

*RISE-SME is a EU-funded project developing a model that can assist companies in detecting and anticipating disruptions in their supply chains. The main outcome of RISE-SME is to build a methodology for different industrial ecosystems that can identify disruptions and technological opportunities for the uptake of advanced technologies in SMEs, so as to enable flexible, agile and resilient supply chains that can easily be adapted.*

***This survey aims to gather insights from European clusters and DIHs about the adoption, maturity, and main barriers for key digital technologies in the textile, agri-food, digital, and automotive sectors****. Your responses will help identify collaboration and technology transfer opportunities for SMEs. Please answer on behalf of your organisation. The survey takes 10–15 minutes, and all answers are strictly confidential.*

To learn more about the RISE SME project click here. To learn more about this survey please contact us at info@rise-sme.eu

## Section A: Contact Details

**Name of Organisation/Cluster:***
*[Short free text field]*

**Country:***
*[Dropdown list of EU countries + "Other"]*

**Contact Person:**
*[Short free text field]*

**Email Address:**
*[Short free text field]*

**Which ecosystem(s) does your organisation represent?***
(Tick all that apply)
☐ Textile
☐ Agri-food
☐ Digital
☐ Automotive

## Section B: General

**What is your organisation's primary role?***
☐ Cluster
☐ Digital Innovation Hub (DIH)
☐ Technology Provider
☐ SME
☐ Other: *[Short free text]*

**How would you describe the overall digital maturity of the organisation(s) you represent?***
☐ Highly advanced (most use advanced digital technologies)
☐ Moderately advanced (some use advanced technologies, most use basic digital tools)
☐ Early adoption (few use advanced technologies, most have minimal digitalisation)
☐ Traditional (mostly non-digital processes)

## Section C: Technology Adoption & Maturity

**Please rate the maturity of each technology among your members/SMEs. For each technology, tick the box that best reflects the majority position in your ecosystem. (If you represent more than one ecosystem, please answer separately for each.)**

**Ecosystem: [Dropdown: Textile / Agri-food / Digital / Automotive ]***

| Technology | Not in use | Pilot/Testing | Minority Use | Many Use | Widely Used | Don't know/NR |
|---|---|---|---|---|---|---|
| Artificial Intelligence | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Internet of Things (IoT) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Digital Twin | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Blockchain | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Data Spaces | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5G Connectivity | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Edge Computing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| AR/VR Solutions | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Robotics | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3D Printing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

## Section D: Technology Gaps & Barriers

**Which of the following are the main barriers to adoption of advanced digital technologies in your ecosystem?***
(Tick all that apply)
☐ High investment/implementation cost
☐ Lack of digital skills / skills shortage
☐ Poor digital infrastructure (e.g., connectivity)
☐ Integration with legacy systems
☐ Data privacy or security concerns
☐ Regulatory or compliance constraints
☐ Lack of awareness of available solutions
☐ Dependence on critical technology suppliers
☐ Unclear return on investment (ROI)
☐ Resistance to change / organisational culture
☐ Other: *[Short free text]*

**Where do you see the greatest need for technology transfer or collaboration?***
☐ Within your ecosystem (e.g., between SMEs)
☐ Between ecosystems (e.g., from digital to textile)
☐ With technology providers (startups, SMEs, large enterprises)
☐ With research organisations or universities
☐ Don't see the need for technology transfer or collaboration
☐ Don't know

## Section E: Impact & Opportunities

**Which technologies have the greatest potential to improve supply chain resilience in your ecosystem?***
(Tick up to 3)
☐ Artificial Intelligence (AI)
☐ Internet of Things (IoT)

☐ Digital Twin
☐ Blockchain
☐ Data Spaces
☐ 5G Connectivity
☐ Edge Computing
☐ AR/VR
☐ Robotics
☐ 3D Printing

**What are the main drivers for adopting advanced technologies in your ecosystem?***
(Tick up to 3)
☐ Cost reduction
☐ Improved adaptability
☐ Increased efficiency/productivity
☐ Regulatory compliance
☐ Sustainability/environmental goals
☐ Market expansion/customer requirements
☐ Risk management/disruption response
☐ Other: *[Short free text]*

## Section F: Supplier Landscape

**Which type of technology suppliers do your members/SMEs mainly work with?***
☐ Large international technology providers
☐ European SMEs
☐ Local/regional solution providers
☐ Mixed / No clear trend

**What are the main criteria for selecting technology suppliers?***
(Tick all that apply)
☐ Price
☐ Proven reliability/reputation
☐ Local presence/support
☐ Alignment with EU regulation
☐ Customisation / flexibility
☐ Innovation capability
☐ Other: *[Short free text]*

## Section G: Follow-up

**Would you like to be contacted for follow-up workshops or interviews?***
☐ Yes (if yes, please ensure your email is entered in section A)
☐ No

## Section H: Privacy

F6S Network Ireland Limited processes names and email addresses, and any other information that might be relevant to RISE-SME based on your consent, to allow it to manage survey responses and to be contacted for follow-up workshops or interviews.
You will have the right to withdraw consent at any time to this processing. The withdrawal of consent shall not affect the lawfulness of processing based on consent before its withdrawal. You can withdraw consent by contacting us at privacyie@f6s.com.

As the data subject, you also have other rights in relation to the processing of your personal data including the right to lodge a complaint with the supervisory authority if you consider processing to be inappropriate. To learn more about these rights please see F6S Network Ireland Limited's privacy policy at this link. If you wish to exercise these rights you can contact F6S Network Ireland Limited by email at privacyie@f6s.com.

☐ I have read the F6S Privacy Notice and I consent to the processing of my personal data for the purposes of the survey.*