ResC4EU
RESILIENT SUPPLY CHAINS FOR EUROPE

D3.1
Mapping of relevant Advanced Technologies and Supply Chain Challenges of SMEs

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Deliverable Lead	Latvian IT Cluster
Lead Responsible	Inese Murniece
Contributing Partners	AID, ATIM, CU, GTW, ISL, MCN, PKTK, SCA
Contributing Authors	Debarschee Bjardwaj (ISL), Aseem Kinra (ISL)
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List of Abbreviations

AIDIMME:	Metalworking, Furniture, Wood, Packaging and Related Technological Institute
ATIM:	Advanced Technologies in Manufacturing Cluster
CU:	Cluster CU Nord of Composites United e.V.
EDIH:	European Digital Innovation Hub
EU:	European Union
ICT:	Information and Communication Technologies
IT:	Information Technologies
LITC:	Latvian IT Cluster
MCN:	Maritime Cluster Northern Germany
NACE:	Statistical classification of economic activities in the European Community, derived from the French Nomenclature statistique des activités économiques dans la Communauté européenne
PKTK:	Polish Cluster of Composite Technologies
SME:	Small and Medium-size Enterprise
UK:	United Kingdom

1 Executive Summary

This document is deliverable **D3.1 Mapping of relevant Advanced Technologies and Supply Chain Challenges of SMEs** of the ResC4EU project. This document outlines the most common industrial supply chain challenges of SMEs, as identified by the ResC4EU project cluster partners, and offers a list of advanced technologies that may have a potential in solving these challenges. The document likewise presents the mapping of the best practices for each industrial sector.

The ResC4EU project focuses on supporting SMEs in building resilient supply chains in 14 European industries. To ensure a common understanding of the SMEs targeted in the ResC4EU project, a list of all 14 European industries as defined by the European Union[1] is presented with more details **which kind of companies count to each sector and how each sector is covered by the ResC4EU cluster partners and its member SMEs**. The targeted 14 industry sectors are:

(1) aerospace and defence,
(2) agri-food,
(3) construction,
(4) cultural and creative industries,
(5) digital,
(6) electronics,
(7) energy intensive industries,
(8) energy-renewables,
(9) health,
(10) mobility, transport and automative,
(11) proximity, social economy and civil security,
(12) retail,
(13) textile, and
(14) tourism.

A landscape of supply chain challenges and capabilities of SMEs was created comprising three identified common supply chain challenges:

(1) vulnerabilities,
(2) risks (weaknesses, gaps, or complexities present all the time or most of the time in the company),
(3) disruptions (unexpected outcome events that interrupt the daily business operations)

and three respective capabilities the companies possess to tackle the challenges:

(1) firm internal capabilities and
(2) supply chain network capabilities, and
(3) IT and digital capabilities.

SME's challenges and capabilities were refined across five common supply chain processes: **(1) planning, (2) inbound logistics: procurement and supply, (3) production, (4) outbound logistics: sales and distribution,** and **(5) product returns and reverse logistics**.

A landscape of common advanced technologies was created comprising the categories: **1) data and storage, 2) software, 3) hardware and materials, 4) navigation and connectivity** and **5) security** and ranging from digital platforms, artificial Intelligence, advanced materials, robotics, and additive manufacturing.

Finally, 14 best practice examples, one for each of the targeted industry sector, were provided to show how advanced technologies could help solving SME's supply chain challenges.

[1] Annual Single Market Report 2021. Retrieved from https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf (accessed 9.07.2024)

2 Introduction

2.1 Purpose of this document

This document is a deliverable **D3.1 Mapping of relevant Advanced Technologies and Supply Chain Challenges of SMEs** of the ResC4EU project. Its purpose is to identify the most common supply chain challenges of SMEs and provide a map of advanced technologies that may have the potential to solve these challenges.

Objectives of this deliverable are:

- To identify supply chain challenges of SMEs in all 14 industrial sectors and summarise them into a landscape of supply chain challenges of SMEs;
- To identify advanced technologies that have the potential to create an impact on the supply chain resilience and climate neutrality and summarise them into a landscape of advanced technologies.
- To provide examples of best practices for each of the 14 industry sectors on how advanced technologies can help overcome the supply chain challenges.

2.2 Document structure

The document is divided in 4 chapters:

- **14 Industrial sectors** (chapter 4) as defined by the European Union and coverage of these sectors by the ResC4EU cluster partners.
- **Landscape of supply chain challenges of SMEs** (chapter 5) showcasing the most common supply chain challenges as identified in 14 industrial sectors by the project's industrial clusters. The chapter initiates with "the need" behind such landscape and concludes with the presentation of the landscape's "classification" that builds a better understanding what challenges appear in what supply chain processes, also including in-depth examples.
- **Landscape of advanced technologies** (chapter 6) showcasing the advanced technologies that are identified as the most relevant in solving the supply chain challenges and follows a similar contextual pattern. The chapter starts with "the need" of the landscape and finalises with the "classification", developed by the project partners, to list the available technologies and their potential applications.
- **Mapping of the supply chain challenges of SMEs and advanced technologies** (chapter 7) linking both landscapes together and introduces the best industrial practices in 14 ecosystems. The mapping will enable the companies to evaluate their supply chain challenges better and see what technologies are available in the market.

2.3 Targeted group

This document is classified as **public**, means for members of the Consortium including Commission Services and for the public.

This document has been created for the ResC4EU project partners:

- as a starting ground for more in-depth research of supply chain challenges and related technological solutions and to engage with SMEs, both SMEs with the supply chain challenges and tech-savvy SMEs with potential technology solutions, in a structured way in task T3.2 and T3.3 of the ResC4EU project as well as in T5.1 focusing on bringing manufacturing SMEs together with tech-savvy SMEs to build potential business connections.
- as an input for building the supply chain risk models in task T4.1 of the ResC4EU project.

In addition, we target SMEs operating in the given 14 industrial sectors and interested to learn more about common supply chain challenges and how advanced technologies can be used to overcome supply chain disruptions. Finally, the document will also be beneficial to all those, interested in the topics of resilience, supply chains and advanced technologies.

3 Methodology

To gather the necessary data, the following key steps were undertaken – see **Figure 1**.

STEP 1: To understand **the landscape of supply chain challenges faced by SMEs**, the partners developed a comprehensive framework that accurately represented the supply chain processes and associated challenges. This framework was used to identify challenges across 14 industrial sectors, as listed in Chapter 5 of this document.

The landscape was made suitable for all 14 industrial sectors at once as the collected challenges were listed in an aggregated form, without identifying a specific industry or company to give a unifying view of the most common supply chain challenges. More examples were added in the landscape's descriptive part in Chapter 5, as well as outlining the best practices in Chapter 7.

STEP 2: The challenges came from each ResC4EU cluster's working experience with the industrial companies, for example, through different digitalisation-related events, direct interviews with the companies, or previously done surveys and reports. See Figure 2 and chapter 4 for full industrial coverage by the ResC4EU cluster partners.

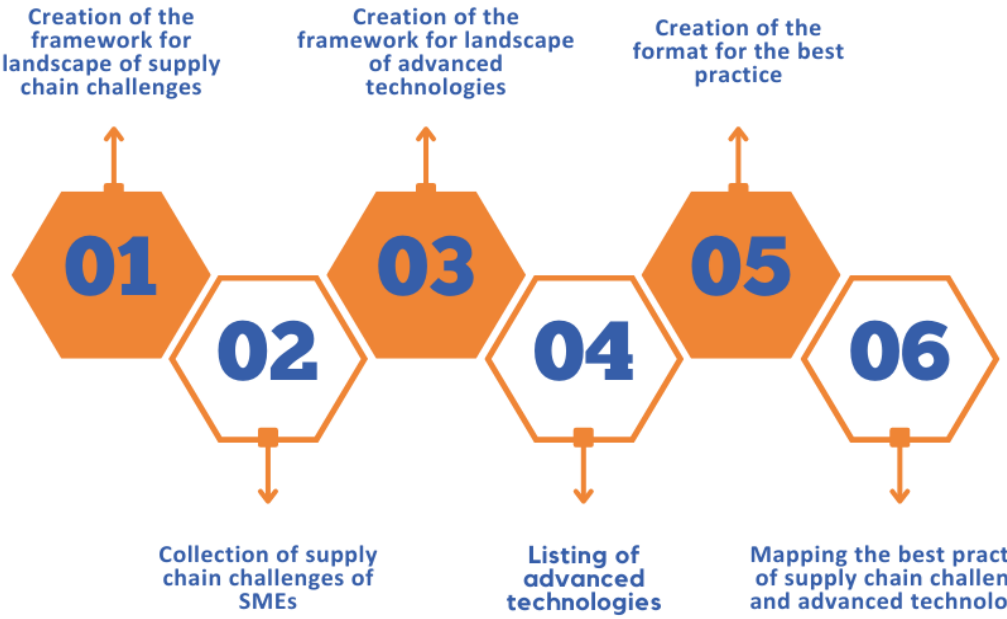

Figure 1: Key steps of the process

STEP 3: For the **landscape of advanced technologies**, the partners crafted the landscape framework that best represented the capabilities of technologies and listed the advanced technologies according to the framework.

STEP 4: The advanced technologies were collected, evaluated, and listed in the landscape, based on the overview of various information sources, including scientific and media. In addition, the feedback was given by the industry and tech partners in the ResC4EU consortium to enrich the landscape.

The selected advanced technologies will focus on the notions of resilience and climate neutrality, as well as sustainability and innovation thinking.

STEP 5 and STEP 6: For the mapping of supply chain challenges and advanced technologies, a unified best practice framework was created and filled with content by the ResC4EU cluster partners, covering all 14 industrial sectors – see Figure 2 and chapter 4.

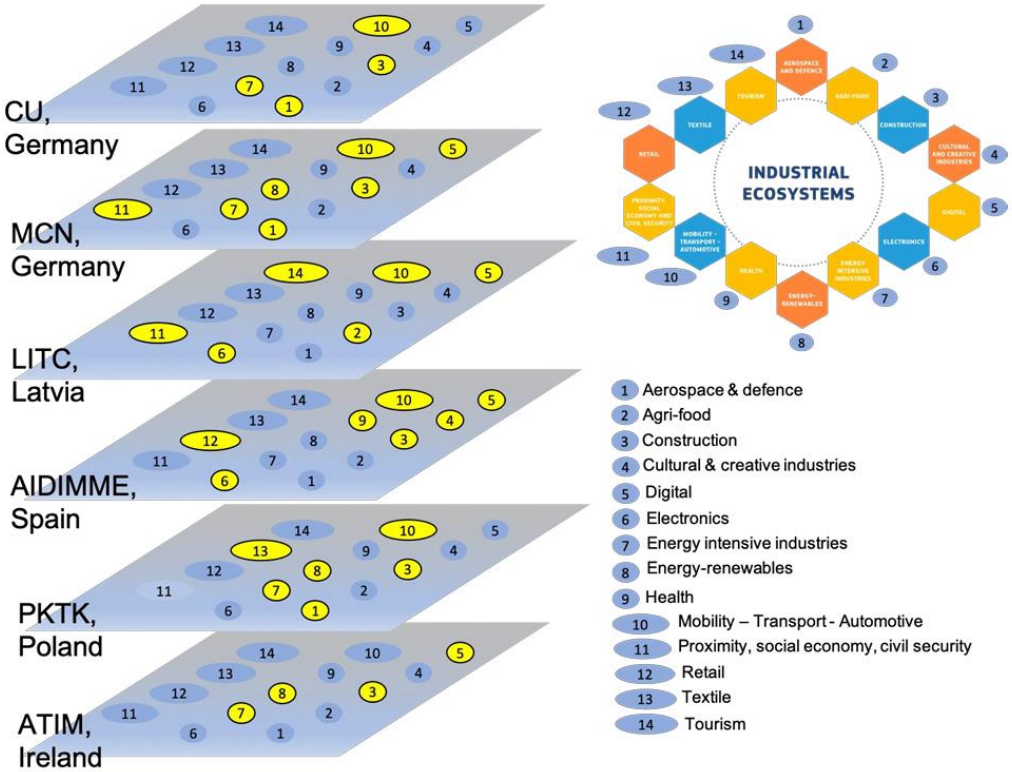

Figure 2: Industry coverage by ResC4EU clusters

4 14 Industry sectors and coverage by ResC4EU cluster partners

Table 1 lists all 14 Industry sectors or 'Industry ecosystems' as defined by the European Union[2] and provides more details which kind of companies count to each sector. In addition, we have listed which of the ResC4EU cluster partner is covering with its member SMEs which sector.

Table 1: 14 Industry sectors as defined by the European Union and coverage by the ResC4EU clusters

Industry	Definition by European Union	ResC4EU cluster
1. Aerospace and defence	The Aerospace and Defence ecosystem covers **manufacturing companies in aeronautics, space and defence**; space operators and data and service providers; research institutes.	CU, PKTK
2. Agri-food	The agri-food ecosystem covers all operators in the food supply chain (**farmers, food industry, food retail and wholesale, and food service**) and their suppliers of inputs and services (seeds, pesticides, fertiliser, machinery, packaging, repair, transport, finance, advice and logistics). The ecosystem hence has a very long border – and overlaps – with the Tourism and the Retail ecosystems.	LITC
3. Construction	The construction ecosystem covers contractors for **building and infrastructure** projects, some **construction product manufacturers**, **engineering and architectural services** as well as a range of other economic activities (e.g. rental and leasing of machinery and equipment, employment agencies).	CU, PKTK, AID, ATIM
4. Cultural and creative industries	The CCIs are a varied group. The biggest industries are **audiovisual** (TV, videogames, VOD, cinema, VR/AR), **music, books and press publishing, advertising, cultural heritage** (museums, historical sites), **performance** (theatre, dance) and **visual arts.**	AID
5. Digital	The digital ecosystem covers **ICT Manufacturing**, **Services** (excluding telecommunications), **Telecommunications**.	LITC, ATIM, MCN
6. Electronics	The electronics ecosystem covers **design and manufacturing of electronic components**; includes raw materials (semiconductor wafers) and **manufacturing tools**. The value chain stretches from design to semiconductor manufacturing to 'assembly-test-packaging' facilities, before reaching end-user companies, which integrate the chips into their product solution. Materials, equipment and related services and tools, including specific	LITC, AID

[2] Annual Single Market Report 2021. Retrieved from https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf (accessed 9.07.2024)

	design tools and so-called **functional blocks**, enable design and manufacturing.	
7. Energy intensive industries	The Energy-Intensive Industries (EIIs) Ecosystem covers **chemicals, steel, paper, plastics, mining, extraction and quarrying, refineries, cement, wood, rubber, non-ferrous metals, glass, ceramics.** They supply intermediate products to each other and to many downstream sectors of the economy, are closely integrated with energy providers as well as with the waste and recycling industries due to their need for secondary raw materials.	CU, PKTK, MCN, ATIM
8. Energy-renewables	Renewables include **wind energy, solar energy** (photovoltaics, thermal and concentrated solar power), **hydropower, bioenergy** (including sustainable biofuels), **geothermal energy**, **ocean energy**, and **heat pumps**. Furthermore, **sustainable energy storage solutions**, **smart infrastructure technologies** and **energy conversion technologies**, including electrolysers, are an important part of a clean energy ecosystem.	MCN, PKTK, ATIM
9. Health	**Manufacturing of pharmaceuticals** and their key inputs, **medical devices and equipment** and **personal protective equipment; Healthcare services** (medical and residential care); **Health tech** and related services	AID, CU
10. Mobility, transport and automative	The Mobility – Transport – Automotive Ecosystem covers **automotive, rail and waterborne**. It is characterised by long and complex supply chain. The ecosystem is dominated by a few players that became global players.	MCN (waterborne); PKTK, CU (automotive, rail), LITC, AID
11. Proximity, social economy, and civil security	The **'proximity economy'** includes services and businesses fostering local and short value chains for mainly local production and consumption. Proximity businesses include **local SMEs operating personal and contact services**, **small shops, bars and restaurants, repair, cleaning and maintenance services**, etc. The proximity economy also acts as the 'last-mile' delivery of goods and services of most of the ecosystems to the local businesses and citizens. The **Proximity dimension** also includes **civil security services** (fire fighters, police forces, emergency teams, etc.), which operate at local level to support and protect citizens (including emergency incidents/disaster response) and are performed by public entities including an important share of volunteering work. The **'social economy'** encompasses a variety of businesses, organisations and legal forms, including **non-profit associations**,	**LITC,** **MCN**

	cooperatives, mutual societies, foundations and social enterprises.	
12. Retail	Retail (large companies, SMEs, online and offline), relevant wholesale, online platforms. E-commerce represents 10-15% of total retail sales (much less for grocery retail). Market concentration differs across EU. The largest are mainly grocery chains, cosmetics, textiles and furniture sellers.	AID
13. Textile	The textile ecosystem includes transformation of natural (e.g. cotton, flax, wool), man-made and artificial (synthetic polyester and viscose) fibres into yarns and fabrics, production of yarns, home textiles, industrial filters, technical textiles, carpets and clothing. The ecosystem also includes production of footwear and leather.	PKTK
14. Tourism	Services providers at destination level (hospitality, attractions) are, in their majority, small local owners. Part of them are franchisees of a few multinational companies providing branding, marketing, management and selling services.	LITC

Through the ResC4EU cluster partners and its SME members, the project has a reach out to approximately 1000 SMEs. The project partners will also approach clusters and its SME members outside the ResC4EU consortium to further enlargement of the network.

5 Landscape of Supply Chain Challenges of SMEs

5.1 The need

In today's business environment, the uncertainty is a part of the business growth. There is a need for longevity of business processes within the supply chain, and that's quite often linked with the notions of innovations, sustainability, and resilience. The latter especially is among the key topics in both the business and political corridors due to the post-Covid consequences and ongoing military conflicts, such as the Ukraine war, that continues to have an enormous effect on the European businesses in terms of reduced export markets, higher energy prices, and limited access to bank loans.[3] If resilient supply chains are to withstand and quickly adapt to various disruptions or changes, while ensuring continuity of operations, and minimise disruptions to the flow of goods or services[4][5], the question is, how to build on resilience and help companies overcome their business struggles in a more efficient manner.

Arguably, the answer pledges the companies to be two-fold, plus operate somewhere in-between. From one hand, they must be company-focused and understand both their inner supply chain processes and the major problems in them. From another – they must be industry-aware and measure how the political, climate and business changes interfere with their company. On top of that, they must be flexible and find the best scenarios for their operations that let them ensure the risk mitigation, business continuity, cost reduction, increased flexibility, sustainability, customer satisfaction, and competitive advantage.[6]

The helping hand comes in the policy and support mechanisms that facilitate the resilience building efforts. The EU's Green Deal Industrial Plan, for example, sets on shaping the continent as "the home of industrial innovation and clean tech",[7] forecasting more funding opportunities for green transition projects and awareness-raising activities, including supply chain resilience.[8] Such support likewise links to different cluster initiatives and events to build on digitalisation, R&D, and talent and skills.[9]

The ResC4EU project adds another input by deploying a landscape of supply chain challenges of the SMEs. Through it, the landscape plans to offer the opportunity to track down different types of challenges and link them with the supply chain processes to ensure a wider view on the overall business picture. Not only

[3] Economic impact of Russia's war on Ukraine: European Council response. Retrieved from https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/757783/EPRS_BRI(2024)757783_EN.pdf (accessed 14.05.2024)

[4] Hald, K. S. and Kinra, A., "How SMEs struggle to develop and balance supply chain resilience capabilities", Paper presented at the 29th International EurOMA Conference 2022 - European Operations Management Association EurOMA, Brilliance in Resilience, Berlin, 2022.

[5] Kinra, A. and Hald, K. (2022), "Building the supply chain resilience of small and medium-sized enterprises", Effektivitet 2022, No. 1.

[6] The ResC4EU Digital Brochure. Retrieved from https://www.resc4eu.com/library.html (accessed 06.06.2024)

[7] Delivering the European Green Deal. Retrieved from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en (accessed 8.05.2024)

[8] Commission opens €4 billion call for proposals for net-zero technologies under the Innovation Fund. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/IP_23_5948 (accessed 15.05.2024)

[9] For the Advanced Technologies in Manufacturing (ATIM) Cluster in Ireland, the cornerstone of the cluster's success is its focus on building resilient supply chains. By working closely with manufacturing companies, both large and small, and engaging key stakeholders, the cluster identifies critical links along the value chain. It brings stakeholders together to address challenges collaboratively, ensuring a robust and adaptable supply network. A recent survey revealed that 94% of members have successfully connected with entities via the cluster to enable their business growth.

it gives a chance to analyse how the challenges affect the growth of the company, but also enables the companies to establish procedures that take preventive actions to address these challenges and maintain the business operations in a moment of crisis. In addition, the framework of the landscape is made to be revised and updated regularly letting the companies adjust the challenges when necessary.

5.2 The classification

For our landscape, we've used various sources and the extensive experience of the ResC4EU project partners to formulate the main characteristics of supply chain challenges, which are:

Process-related to cover all operations of the supply chain in an in-depth manner. IBM[10], for instance, accentuates 5 key processes, such as **planning, sourcing, manufacturing, delivery and logistics, and returning**, that closely follow the widely accepted SCOR[11] (Supply Chain Operations Reference) model for supply chain management. We will take a similar pragmatic approach to one part of the landscape as the SMEs often face process-related supply chain challenges that can hinder their efficiency and growth, for example, limited resources and budget constraints can lead to inefficiencies in planning, procurement, and logistics.

Challenge-related to have a wider view at the supply chain problems of SMEs. To tackle this idea, we will form the second part of the landscape and classify the **challenges (or vulnerabilities)** in each of the supply chain processes and place them against the **capabilities** that the companies must possess to face these challenges and reach a state of balance, and thereby resilience.[12][13]

Industry-inclusive to address the 14 industrial sectors all at once. For this, the project cluster partners will identify an initial set of the **most common challenges** that are present **in their specific industries** and define them as aggregated sub-categories. It means, not all challenges may be present in all industries, and some challenges may be present in all industries.

Open-ended to initiate a further discussion on adjusting the landscape of SMEs' supply chain challenges. As the challenges tend to change, shift, or evolve, we acknowledge that the sub-categories may not be exhaustive or final. We believe the landscape should be flexible, yet measurable and relatable to the companies involved.

With these characteristics in mind, we propose the following landscape of supply chain challenges as presented in **Table 2**.

[10] What is supply chain management? Retrieved from https://www.ibm.com/topics/supply-chain-management (accessed 9.05.2024)
[11] Introduction to Processes. Retrieved from https://scor.ascm.org/processes/introduction (accessed 14.08.2024)
[12] Hald, K. S. and Kinra, A., "How SMEs struggle to develop and balance supply chain resilience capabilities", Paper presented at the 29th International EurOMA Conference 2022 - European Operations Management Association EurOMA, Brilliance in Resilience, Berlin, 2022.
[13] Pettit, T. J., Croxton, K. L., & Fiksel, J. (2013). Ensuring supply chain resilience: development and implementation of an assessment tool. Journal of business logistics, 34(1), 46-76.

Table 2: Landscape of Supple Chain Challenges and Capabilities of SMEs

	Planning	Inbound logistics: Procurement and Supply	Production	Outbound logistics: Sales and Distribution	Product returns and reverse logistics
Vulnerabilities	• Labour shortages, including talent retention and learning new skills • Limited resources for data management, demand forecasting and strategic procurement • Adapting to remote work models and digital transformation	• Supplier and material quality issues • Supplier susceptibility to external forces • Raw material shortages • Ethical sourcing of raw materials and sustainability requirements • Difficulties in managing supplier relationships and ensuring timely delivery of materials	• Product complexity • Manual work • Time-consuming production process • Labour shortages • Energy shortages • Inadequate process optimisation	• Demand fluctuations • No communication/ marketing/ sales strategy • No data analytics/ management • Struggle to adapt to e-commerce and omnichannel distribution • Transportation delays • No fleet traceability • Poor coordination and insufficient infrastructure	• Product/ service defects • Recall/ refunding events • Low relationships with out-sourced maintenance services • The lack of support centres
Risks	• Geopolitical instability and legal framework change, e.g., trade regulations • International trade policy and tariffs • Low-hanging fruit strategy • Forecasting inability and ineffective business management • Inadequate resource allocation	• Supplier dependency risks, including unreliable suppliers, delays in material delivery, fluctuating costs • Compliance risks • Geopolitical instability and dependence	• Production process risks, including equipment failures, labour shortages, quality control issues • High percentage of errors/ defective products • Cyber security threats to manufacturing systems	• Demand volatility • False/ imprecise marketing decisions • Transportation delays and inadequate warehousing	• Return process risks, including return logistics and management of associated costs • Warranty liabilities • Struggle to adapt the principles of circular economy and managing returns sustainably

Disruptions	• Natural disasters • Inventory/ technology issues • Rising costs • Sudden market changes	• Supplier bankruptcy • Defects in the supplied materials • Supplier failures	• Machine breakdowns • Power outages • Labour strikes • Quality control issues	• Transportation strikes • IT system failures • Transportation route blockage • Transportation breakdowns, accidents, or natural disasters • Product damage during the transportation • Sudden regulatory changes • Sudden market changes	• Return processing errors • Damage during re-send • High return volumes or recalls • Difficulties in refurbishing or recycling returned products
Firm internal capabilities	• Self-development programmes for employees • Internal innovation, sustainability, and resilience strategies • Developed resilience strategies	• Supplier diversification strategies • Risk mitigation plans • Localisation of supply chains • Effective negotiation procedures and matchmaking skills	• Maintenance programs • Production flexibility • Use of fluctuating renewable energy • Workforce training	• Control of logistics • Developed marketing and communication strategies, procedures and protocols • Openness towards creative sales and marketing approaches	• Reverse logistics capabilities for recycling or refurbishing products • Customer service procedures and communication guidelines • Customer service protocols
Supply chain network capabilities	• Network/ supply chain optimisation • Access to diverse sourcing options, including alternative suppliers	• Responsive supplier relationships	• Production network optimisation, including agile	• Distribution network optimisation • Collaborative logistics partnerships	• Reverse logistics network optimisation • Collaboration with service providers

			• manufacturing practices • Collaborative manufacturing partnerships		
IT and Digital Capabilities	• Enterprise resource planning (ERP) systems • Business analytics systems • Administration systems • AI-based demand forecasting tools	• Supplier relationship management (SRM) software • Risk assessment tools • Supplier collaboration platforms • Supplier performance monitoring systems • Blockchain for supply chain transparency • Digital platforms that enhance supplier communication and support matchmaking, risk assessment, resilience strategy built • Inventory management systems	• Manufacturing execution systems (MES) • Predictive maintenance software • Advanced robotics and automation • Maintaining quality standards digitally • Integration of Industry 4.0, Industry 5.0 and smart manufacturing strategies	• Customer relationship management (CRM) software • Communication and marketing applications • Product tracking • Fleet management systems • Cross-border logistics and compliance • Inventory visibility across multiple locations	• Reverse logistics software automated return and return tracking • Warranty management systems • Chatbots

Table 2 illustrates a matrix approach to the supply chain challenges of SMEs. The horizontal categories envelop the defined **five supply chain processes: (1) planning, (2) inbound logistics: procurement and supply, (3) production, (4) outbound logistics: sales and distribution, and (5) product returns and reverse logistics**. In the case of the traditional service-based industries, such as tourism, creative industries, or health, the production process is interpreted as the activities before the service operations are performed: preparing to host guests or patients, or concert attendees.

The vertical categories distinguish the respective **three supply chain challenges: (1) vulnerabilities, (2) risks** (weaknesses, gaps, or complexities present all the time or most of the time in the company), **(3) disruptions** (unexpected outcome events that interrupt the daily business operations). In addition, the vertical categories outline three respective capabilities the companies possess to tackle the challenges: **(4) firm internal capabilities** and **(5) supply chain network capabilities**, and **(6) IT and digital capabilities.**

5.2.1 Planning

The planning process in the supply chain showcases the foundation and integrity of the business and is speculatively the most direct and inexorable process of all. It oversees the business operations from HR to production and reacts accordingly to ensure the operations continue. With the data collected from different departments, the companies can analyse their results and make forecasts on business operations and growth.

In this section, the ResC4EU cluster partners highlight 3 areas of challenges: workforce, equipment and technologies, and omnipresent external conditions.

Labour shortages and talent retention are among the most common problems relating to workforce, especially in industries with high employee turnover and long working hours, such as the manufacturing, construction, maritime, and retail industries. The daily questions the companies deal with include the lack of employees, ageing of employees (no generation change), as well as departure of industry expats to better-paid positions outside the European Union (e.g., the UK).

Equipment and technology closely align with labour challenges and significantly impact business operations across all industrial sectors. In various use cases, the companies work with old or inadequate equipment or technologies, leading them to risks of error-packed operations (e.g., physical notebooks still track down what is done in the company), as well as forecasting and monitoring inability (e.g., scarce and scattered data or no data to analyse result in ineffective business management).

Finally, the **always-present outside conditions** play a significant part in the planning process, especially in those supply chains that are long, cross-sectoral, and cross-border. Though such risks and disruptions as geopolitical instability, trade regulations or natural disasters require the companies to work on ad-hoc basis and be adaptable in their supply chains, yet – quite often – these challenges are sudden, rather than previously identified for many companies.

These challenges require the companies to reflect on their IT and digital capabilities, including investing in technologies that help automating manual work, for example, testing advanced technologies in the maritime industry such as digital twins, augmented reality (AR) or even exoskeletons, or improving the overall business operations, for example, implementing enterprise resource planning (ERP), administration, and business analytics systems in all industrial sectors. It likewise involves strengthening the internal firm's

capabilities and introducing self-development programmes for employees, for example, integrating the continuous learning and training programmes from the planning phase onwards to empower their workforce to adapt to future supply chain challenges and be able to effectively use advanced technologies in their processes. As noted by the clusters, the Ukraine war and the following EU sanctions on Russia and Belarus have made the companies re-evaluate their internal capabilities and work on innovation, sustainability, and resilience strategies to leave the survival mode.

5.2.2 Inbound logistics: Procurement and Supply

The inbound logistics cover the procurement and supply management process and are crucial in delivering the raw material for the production process that follows. The role of the process is to examine and maintain the relationships with the suppliers, as well as be aware of the potential alternatives of supplies, thus making it – alongside the outbound logistics – the most dependable on the outside factors and conditions.

Here, as noted by the ResC4EU cluster partners, 2 types of challenges can be identified: supplier-related and material-related challenges.

Supplier-related supply chain problems apply to the relationships built between the two or more parties in the deal, and among the key challenges are supplier quality issues, supplier dependency risks, as well as supplier bankruptcy or suspension of operations. For example, this could imply that a supplier's reputation is less than ideal, causing relationships to become unpredictable and tense, particularly if the business relies on a single supplier. External factors have also posed challenges to these relationships. For example, the lingering effects of the Covid-19 pandemic are still visible as many companies/ suppliers who had stopped their operations due to physical work limitations have faced difficulties in fully reopening and operating at pre-pandemic capacities.

Similar notions can be observed in the material-related challenges, where raw material shortages and defects in the supplied materials interfere with the company's operations. For instance, the sanctions on Russia and Belarus due to the Ukraine war have affected the supplying markets in the manufacturing and construction industries. Also, poor harvest due to weather conditions (excessive heat or thunderstorms) have decreased the selling range of the material and skyrocketed the purchase prices in the agriculture industry. On top of that, the local disruptions, such as damaged supplied material units, can postpone the whole production process for an unknown period.

In such scenarios, the best practice is to preventively plan and work on supplier diversification strategies, supplier collaboration platforms, and risk assessment tools. These capabilities can both offer a clear view of what's happening in the supply chain (and therefore make analytic decisions if necessary) and propose potential supplier or material alternatives to strengthen the very supply chain, e.g. local sourcing, alternative materials, partnership with resilient suppliers which are known for their resilience and proactive risk management strategies.

5.2.3 Production

The production is widely considered as the most demanding, costly and complex process of the supply chain being responsible for building products or preparing services to the customers. It is likewise the

process that employs the most people and typically requires the longest time to complete, thereby presenting numerous potential challenges to supply chains.

The ResC4EU cluster partners refer to the labour shortages, product/ service quality control, and the overall process complexity as the most common challenges related to production.

The labour shortages interlink with the planning process as the two processes must work hand in hand to ensure the manufacturing or service providing doesn't stop[14]. The shortages caused by different reasons are present in all industries, starting from low-paid positions (e.g., low-qualified jobs in manufacturing or low government funded jobs in health) to monotonous work tasks and long working hours (e.g., manual work in manufacturing or cleaning services in tourism) to regional attractiveness (e.g., it's more difficult to find employees in rural areas with small population levels). All that make the companies think not only about how to attract and retain employees, but also how to align with their cultural habits, norms, and characteristics.

The product or service quality control can be compromised by the labour shortages, although it is not always the case. For example, the manual, low-skilled, and repetitive tasks and long working hours increase the risks of quality control, potentially leading to higher error rates and defective products and services. Additionally, the quality can also be impaired by machine breakdowns or power outages during the process, as well as inappropriate technologies or equipment to work with. The clusters note, in the case of the latter, sometimes it's not because the companies don't want to invest in technologies, sometimes they are limited by the availability of suitable technology or equipment on the market.

The complexity of the overall production process is the last domain, where addressing and enhancing it could potentially resolve the challenges in the preceding domains. Such challenges as time-consuming production process and reliance on the manual labour involve many employees and multiple production steps that eventually reduce the flexibility and efficiency and open a place for errors, whether they are human-introduced or due to machine malfunctions.

To tackle these challenges, the companies look at automating and digitalising the manual work to omit the unnecessary production steps or human intervention, or both. It includes, for instance, the manufacturing execution systems (MES) and predictive maintenance software to make the process more adaptable, resilient, and innovative in the production decisions. It also includes assistance systems such as augmented reality tools, robotics, exoskeletons, and artificial intelligence to increase the efficiency and productivity. In the maritime industry, for instance, the companies are engaged in the introduction of new technologies that can compensate for or cushion the shortage of skilled labour to some extent. For this reason, there is a strong exchange between the maritime industry and applied research.

[14] Brusset, X., Davari, M, Kinra, A. and Davide La Torre (2023): Modelling ripple effect propagation and global supply chain workforce productivity impacts in pandemic disruptions, *International Journal of Production Research*, DOI: https://doi.org/10.1080/00207543.2022.2126021

5.2.4 Outbound logistics: Sales and Distribution

The outbound logistics deal with the sales and distribution process, working on creating marketing and communication strategies, as well as managing product delivery options. The process is heavily dependent on the outside factors, hence the key is the client retention, as well as precise and fast deliveries.

In terms of sales, the ResC4EU clusters point out the vulnerabilities that are present in all 14 industrial sectors: the lack of robust marketing, communication, and sales strategies and lack of customer data analytics. They increase the likelihood of inaccurate sales decisions, posing risks to both company's reputation and revenue streams. Sales are heavily influenced by the demand fluctuations and volatility where the clients and customers can shift from one product to another, from one supplier to another for a better price, deal or relationships. For instance, the focus on one region or country without diversifying the sales strategies has left many companies out of business, if the market is closed, or cut out of opportunities, if the market trade regulations have changed.

In terms of distribution, the biggest challenges happen on the road or at sea: delays, strikes and route blockages, and fleet breakdowns or accidents, as well as piracy and regional conflicts. For example, the recent Europe-wide farmer protests disrupted many traditional logistics routes, causing slowdowns or complete blockages and prompting the companies to seek for the alternative routes. Similar situations also occur during major public events, such as marathons, cycling rides or concerts, which can again close the logistics routes. On top of that, many companies still face challenges in effectively scheduling their distribution routes, trace their fleet, and react to problems in the real time, resulting in the product delays, unsatisfied customers, and additional expenses.

In the maritime logistics, such factors as the piracy (e.g., Somalia) or regional military conflicts (e.g., the Israel or Ukraine war) affect the supply chains significantly. By increasing the security measurements or opting for alternative solutions, the longer routes ultimately lead to higher costs for both the shipping company and the customers. Moreover, the recent incidents like the grounding of Ever Given in the Suez Canal led to a traffic jam of 100 container ships and had a huge negative impact on the global trade.

The companies have a range of capabilities and opportunities to address these challenges, including various IT and digital applications. For sales management, Customer Relationship Management (CRM) systems offer efficient customer interaction tracking and management. Fleet management systems streamline distribution operations, providing real-time tracking and optimisation of delivery routes. Additionally, collaborative logistics platforms enable companies to share resources and optimise the transportation networks, reducing costs and enhancing efficiency. These IT and digital solutions empower the companies to navigate complex outbound logistics process more effectively while improving overall operational performance.

5.2.5 Product returns and reverse logistics

The process of product returns and reverse logistics is the last category for the ResC4EU supply chain landscape and comes into play when there are failures in the production and/ or outbound logistics: the product or service is deemed defective or not meeting the customer expectations and is sent back or cancelled. In addition, the process initiates the substitution, maintenance, or refund mechanism. The complexity of the process lies in the necessity to investigate both the external factors to understand why

the customers didn't like the product or how to repair the product and re-send it to the customer and internal factors to detect what led the products to be defective.

Thus, to summarize the challenges identified by the ResC4EU cluster partners, the issues lie in the **product or service defects, recall or refunding events,** and **warranty liabilities**. However, two key challenges in this process stand out: **the absence of support centres** indicating inadequate client support strategies and procedures and **weak relationships with the out-sourced maintenance services** reflecting insufficient quality control over their services. These challenges are crucial not only in manufacturing industries, but also in the service-based industries for establishing and preserving a positive reputation that encourages the clients to come back and recommend products and services to others.

To strengthen the company's position in returns and reverse logistics' process, the first step is to recognise its significance. Many companies across different sectors still do not integrate this process into their supply chain, often reacting only when issues arise. Still, implementing strong customer service procedures and communication guidelines are crucial in handling support matters effectively. In addition, optimising the reverse logistics networks and fostering the collaboration with the service providers improve the product and service quality control, raising awareness, professionalism, and brand reputation for both the employees and clients.

5.3 Concluding remarks

The created landscape shows that the supply chain challenges of SMEs on daily basis have become diverse and cross-industrial, and some of their challenges (i.e. labour shortages, rising costs, quality control risks) are present in all industrial sectors. These challenges are constantly influenced by the internal and external vulnerabilities, risks, and disruptions, and to build on resilience, the companies must clearly understand what these challenges are, how they change over time, and what effect they have on the company operations. Not only it improves the overview on how the company is run, it also ensures the readiness in procedures and resources to overcome these challenges.

The created landscape was used to create a complementary landscape, namely the landscape of advanced technologies, in chapter 6 of this document. Already one of the capabilities that helps companies work on their business problems is the IT and digital capabilities. In addition, the ResC4EU project partners have identified numerous examples on how advanced technologies add to the company's potential and competitiveness.

6 The landscape of Advanced Technologies

6.1 The need

'Advanced technologies' is the new buzzword to solve business challenges and comprises all from artificial intelligence to blockchain to Internet of Things, robotics, and advanced materials.

On one hand, we can highlight that they are newer, hardware- and software-related, higher in efficiency and performance, and more complex in their technical architecture that are necessary in the manufacturing process.[15] On the other, they are "still immature", but with a promise "to deliver a significant value",[16] as well as be the driving force for "innovative business models and new processes", "greener economy" and "entirely new industries".[17]

Speculatively, such characterisation gives the businesses an opportunity to always stay up to date and be, in a sense, tech savvy not to lose the competitive edge. It lets them follow and learn the tech trends, build the technological expertise that is specifically relevant to the company's industry, as well as establish some sort of forecasting ability to envision of what comes next. Yet, as we note in the DESI 2024 indicator[18] of SMEs with at least a basic level of digital intensity, it is not always the case – see Figure 3.

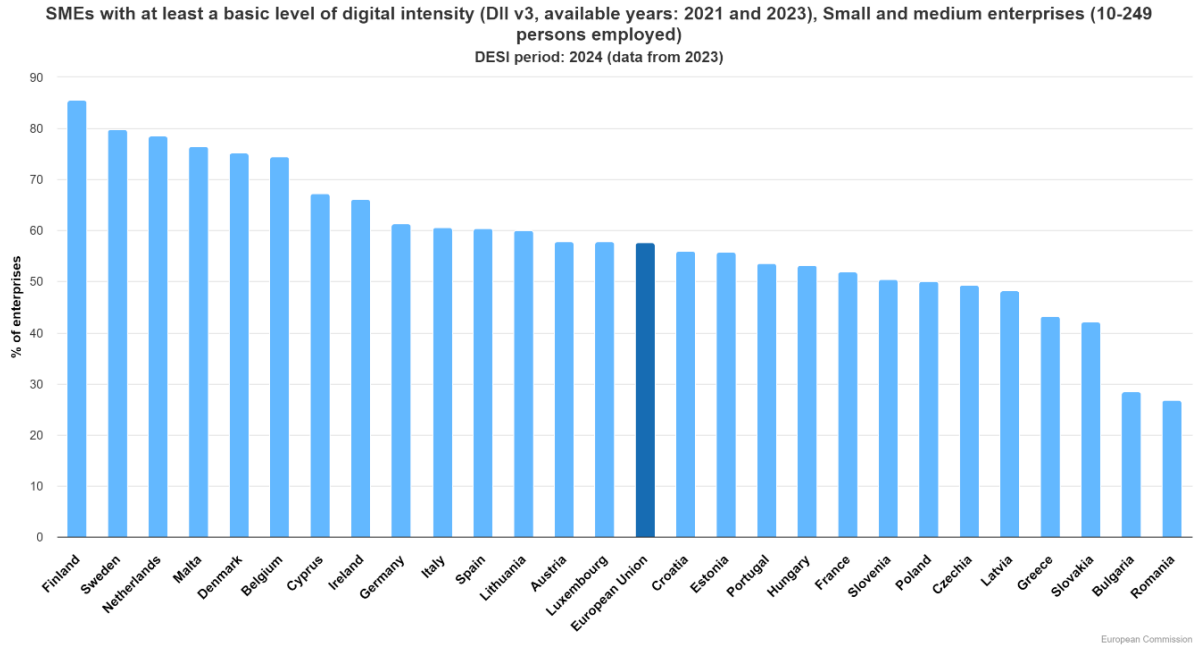

Figure 3: SMEs with at least a basic level of digital intensity

[15] Alina, Kadyrova. (2015). Approaches to Statistical Measurement of Advanced Technologies: A Comparative Study. Social Science Research Network, Available from: 10.2139/SSRN.2610676. Retrieved from: https://typeset.io/papers/approaches-to-statistical-measurement-of-advanced-6l2njs5pv3 (accessed 4.07.2024)

[16] Advanced Technology. Retrieved from https://www.gartner.com/en/information-technology/glossary/advanced-technology (accessed 3.07.2024)

[17] Advanced technologies. Retrieved from https://single-market-economy.ec.europa.eu/industry/strategy/advanced-technologies_en (accessed 3.07.2024)

[18] DESI dashboard for the Digital Decade (2023 onwards). Retrievied from https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/charts (accessed 29.07.2024)

The average EU percentage of digital intensity of the SMEs is 57.7% (in comparison: 69.1% in 2023 and 54.8% in 2022) with Finland topping the table with 85.6% and Romania completing it with 26.8%. The numbers fluctuate, but we can argue that the companies continue to be precautious about what to do with the technologies, such as artificial intelligence or big data, and how to integrate them into their business operations and supply chains, especially if we speak about the EU widening countries.

To close the gap between what's expected and what's the real picture, the governing bodies and industrial organisations have already given the advanced technologies a frequent presence in the policies and support business schemes aimed at igniting the research and development activities within the companies. The European Commission, for example, develops numerous initiatives to strengthen the understanding of advanced technologies and their relation to digital transformation, such as Advanced Manufacturing Support Centre, European Monitor of Industrial Ecosystems, and Digital Innovation Hubs[19], while the clusters support the companies through different topic-related practical digitalisation trainings, masterclasses, hackathons, and informative webinars[20]. These very events have outlined that the companies want to innovate, but they don't understand how to do it properly, as well as they lack guidance in how to navigate through the technological solutions that are promoted via media or EC funding calls and find those that are really in line with their supply chain challenges.

Thus, with our created landscape of advanced technologies, we concentrate at classifying these technologies and easing the task for the companies to increase their tech knowledge. Moreover, we use the previous landscape of supply chain challenges as the base point to locate the technologies that interlink with these challenges and therefore could be of value in solving them.

6.2 The classification

For the landscape of advanced technologies, we've explored different intakes on technological descriptions, classifications and taxonomies, as well as insights of the ResC4EU project partners on the topic to determine the framework we can depend on:

Technology-related supply chain mitigations to focus on the technological capabilities across layers. Traditionally, the interaction between the hardware (physical) and software (digital) technologies has been the core in defining the advanced technologies. However, today's technology landscape extends beyond the hardware or software alone; it incorporates the economic, social, and even political influences, such as those seen in the EU'S Cybersecurity Act or Data Act. Thus, we aim at creating a dynamic and comprehensive framework of technology's capabilities and potential impacts and categorise the advanced technologies into **4 layers**:

- **data layer** to ensure an adequate data availability,
- **software and hardware layer** to facilitate the digital or physical information deployment,

[19] Advanced technologies for industry support and tools. Retrieved from https://single-market-economy.ec.europa.eu/industry/strategy/advanced-technologies/support-tools_en-(accessed 13.05.2024)

[20] As an EDIH, Latvian IT cluster hosts practical Kickstart digitalisation trainings for micro, SMEs and large enterprises to increase their knowledge on different digital transformation topics, evaluate their own business processes and challenges within, as well as learn to assess a wide range of digital tools that have a potential of solving these challenges: https://www.kickstart.lv/

- navigation and connectivity layer to ensure the interoperability across applications and platforms,
- security layer to ensure the protection and support of all preceding layers.

With that, it's crucial to recognize that these layers are interconnected, promoting continuous integration and synergy among technologies.

The respective technology sub-categories are then gathered and examined by the ResC4EU project partners to outline their practical experience about the technologies and potential these technologies may have on the resilience and sustainability of the supply chains. The results therefore serve as an initial classification of technologies, inviting further research and comprehensive comparisons among advanced, emerging, and disruptive technologies. At this stage of the landscape, it has been decided to simplify the classification and categorize all these technologies collectively as advanced technologies.

Industry-inclusive supply chain mitigations to cover all 14 industrial sectors at once. This approach seeks to identify advanced technologies that are applicable across one or more industries, or universally beneficial. Emphasizing simplicity and accessibility in terminology is key to engaging a wide audience of companies. By using popular and generic language, the landscape attracts a broader range of industry participants, facilitating easier adoption and implementation of technological solutions and enhancing the supply chain resilience and efficiency.

Open-ended approach to invite a further discussion on strengthening the landscape and incorporating new notions over time. Recognizing that technologies evolve rapidly, our current landscape serves as an initial attempt to list technologies without finality. This approach encourages flexibility and adaptation, ensuring that we remain responsive to emerging trends and advancements in technology.

Table 3 presents the landscape, and the chosen categories are data and storage, software, hardware and materials, navigation and connectivity and security. They promote various interactions among the advanced technologies and focus on increasing the productivity, efficiency and competitiveness of industries.

Table 3: Landscape of advanced technologies

Data and storage	Software	Hardware and materials	Navigation and connectivity	Security
Data management and analytics: • Big data platforms • Data lakes • Data warehousing • Data virtualisation • Data catalogues	Artificial intelligence (AI): • Machine learning (Deep learning, Natural Language Processing) • Machine vision (Computer vision) • Generative AI technologies (Image, text, audio generation) • Modelling (Digital twins, Simulation) • Decision making based on data	Advanced materials: • Composite materials • Nanomaterials and nanotechnology • Biomaterials • Polymeric materials • Metallic materials • Ceramic materials • Hybrid materials • Functional materials	Satellite-based navigation systems: • Global positioning system (GPS) • Global navigation satellite system (GNSS), such as Galileo (EU), BeiDou (China), NavIC (India) • Assisted GPS	Physical security: • Biometry • Identity and access management • Alarm and emergency systems • Monitoring
Storage technologies: • Solid-state Drives (SSDs) • Hybrid storage • Data centres • Servers	Advanced computing • Edge computing and HPC • Quantum computing • Cloud computing (Infrastructure/ Platform/ Software as a Service)	Advanced manufacturing: • Robotics • Additive manufacturing (3D printing) • Internet of Things (IoT) and Industrial Internet of Things (IIoT)	Indoor positioning systems: • Wi-Fi • Bluetooth	Cybersecurity: • Data encryption • User Identity Management • Spyware • IT security analytics
Data governance and backup: • Data classification and tagging • Data privacy and protection • Backup and recovery solutions	Digital platforms • Supply chain platforms • Transport management platforms • Warehouse management platforms • Risk management and compliance systems	Advanced electronics: • Sensors • Lasers • Drones • Flexible electronics • Wearable electronics, including exo-skeletons • Photonics and optoelectronics	5G/ 6G and beyond	Information security: • Data encryption • Secure API • Password protection • Identity Management Solutions with User Authentication and Authorization, e.g. with role-based access control (RBAC), multi-factor

• Disaster recovery planning				authentication (MFA), single sign-on (SSO), one-time-password (OTP) • Compliance management (e.g. GDPR)
Specific data applications, based on: • Virtual reality (VR) • IoT • Earth Observation • Cloud computing	Extended reality (XR): • Virtual reality (VR) • Augmented reality (AR) • Mixed reality (MR) • Haptic feedback • Spatial audio Eye tracking	Advanced energy technologies: • Next-generation batteries • Energy storage solutions (Fuel cells) • Renewable energy technologies (solar, wind, hydro) • Electrolysers • Carbon capture and storage • Environmental Monitoring		
	Blockchain: • Blockchain platforms • Smart contracts Cryptocurrencies and Digital Assets	Advanced transportation and mobility: • Electric vehicles • Autonomous vehicles • Urban air mobility		

6.2.1 Data and storage

The first category relates to data and storage, outlining the data management and analytics, data storage technologies, data governance and backup technologies, and specific data applications and providing the core asset in today's technology research and advancement – information. With a rise of necessity to perform the business tasks smarter, the information is where this smartness is derived from. For companies, in a raw form the data may mean nothing, in correlation with other technologies the data mean business and supply chain analytics and forecasting, monitoring and development.

For example, the data lakes as repositories of large variety of data[21] can help energy extensive industries store and analyse information from power grids and learn where the energy losses are and how to use it more effectively. Likewise, in the retail industry the data helps collecting and analysing the customer habits and experiences and therefore offer more personalised services for them. On top of that, the data and governance and backup solutions ensure that personal client information and commercial business information are always safeguarded and stored according to national, regional, and international policies and laws.

6.2.2 Software

The second category is the software technologies that ensure the digital deployment of supply chain operations and serve as the next generation programming. We've placed the AI, advanced computing, digital platforms, blockchain and XR under its umbrella for this landscape iteration. For companies, it offers a digital context and intelligence to business activities, completing complicated and diverse activities, potentially multiple at the same time.

For instance, in interaction with data and robotics, computer vision gives the opportunity to detect product anomalies in manufacturing industries and decrease the number of errors in the sorting process, and not only.[22] Also, in the maritime industry – in interaction with data and security –, digital twins are more and more used by the shipyards and shipping companies offering a great added value for the vessel production process (especially when multiple companies are involved in production and it's difficult to set standards and IP rights and track down the progress), the after-sales process and security of supply. Also, the modern Enterprise Resource Planning (ERP) platforms,[23] interlinking digital platforms, cloud computing, data management and security, regularly work on technology advancements and more dynamic support in analytics, monitoring and forecasting in real time, crucial for all industries. Finally, in a strong interaction with wearables and data, the augmented reality applications transform the marketing processes providing new approaches in the customer experiences and engagement.[24]

[21] Webinar Wrap-up: Impact of Data Lakes on Digital Transformation and Analytics. Retrieved from https://www.simplilearn.com/impact-of-data-lakes-on-digital-transformation-and-analytics-article (accessed 23.04.2024)
[22] Take A Look At Innovative Applications Of Computer Vision. Retrieved from https://www.forbes.com/sites/forbestechcouncil/2024/02/16/take-a-look-at-innovative-applications-of-computer-vision/?sh=4d00a640f548 (accessed 22.04.2024)
[23] What Is SAP ERP? Retrieved from https://www.forbes.com/advisor/business/what-is-sap-erp/ (accessed 22.04.2024)
[24] 3 Ways Augmented Reality is Taking Customer Experience to the Next Level. Retrieved from https://www.entrepreneur.com/en-in/growth-strategies/this-is-how-you-can-enhance-your-customer-experience-with/336647 (accessed 22.04.2024)

6.2.3 Hardware and materials

The third category – hardware and materials – refer on physical deployment of supply chain operations, bringing physical materials and gadgets into equation and resulting in such sub-categories as advanced materials, advanced manufacturing, advanced electronics, advanced energy technologies, and advanced transportation and mobility technologies.

Combining drones, sensors, satellite-based navigation systems and data management into IIoT, the agriculture businesses can make better decisions in resource planning and increase sustainability.[25][26] Also, in interaction with drones and next-generation batteries, new improvements in drone battery management during the flight missions can be made, and that's crucial for the aerospace and defence industries.[27] Finally, though this category is traditionally more referable to manufacturing, scientific and energy-intensive industries, we can also identify hardware technologies in other industries, namely robotic assistants in tourism.[28]

6.2.4 Navigation and connectivity

The fourth category encompasses the navigation and connectivity technologies, having satellite-based navigation systems, indoor positioning systems, and 5G/6G and beyond as its sub-categories. The category depends on its interoperability function, offering access for other technologies to communicate in wider networks and operate in larger and more complicated environments. For companies, it enables their devices and technologies to be interconnected and always located in and from any location, no matter the size and complexity of their data.

For instance, the 5G technology becoming one of the most vital technologies to work with. As CISCO puts it, "it is designed to increase speed, reduce latency, and improve flexibility of wireless services" making it ideal not only for business applications, but for "online gaming, videoconferencing, and self-driving cars",[29] too. The deployment of 5G infrastructure is likewise supported by the EU's programme CEF Digital that has recently signed 37 new grant agreements, worth of 252 million euros, to support connectivity, and resilience in numerous industries, including civil security and defence.[30]

[25] Industry 4.0: The Fourth Industrial Revolution. Retrieved from https://iotbusinessnews.com/2024/01/30/56566-industry-4-0-the-fourth-industrial-revolution/ (accessed 23.04.2024)
[26] Industrial IoT a key force in reducing the environmental impact of the agriculture sector. Retrieved from https://www.farmprogress.com/conservation-and-sustainability/industrial-iot-a-key-force-in-reducing-the-environmental-impact-of-the-agriculture-sector (accessed 23.04.2024)
[27] Drones: the leading companies in automated drone battery management revealed. Retrieved from https://www.airport-technology.com/data-insights/innovators-drones-automated-drone-battery-management-aerospace-and-defense/?cf-view (accessed 23.04.2024)
[28] Meet Sara – Emirates' new robot check-in assistant. Retrieved from https://apex.aero/articles/emirates-robot/ (accessed 23.04.2024)
[29] What Is 5G? Retrieved from https://www.cisco.com/c/en/us/solutions/what-is-5g.html (accessed on 25.04.2024)
[30] Over €250 million to support secure connectivity across the EU under the CEF Digital Programme. Retrieved from https://digital-strategy.ec.europa.eu/en/news/over-eu250-million-support-secure-connectivity-across-eu-under-cef-digital-programme (accessed 24.04.2024)

6.2.5 Security

The final category of the landscape is the security technologies with focus on security, including physical, cyber and information. For companies, these technologies come with the protection for their physical and digital assets that maintain the business operations and competitiveness.

Cyber-attacks are often aimed at companies and their critical infrastructure. In 2022, a cyber-attack[31] led to the disruption of the satellite network and consequently to the loss of control of several thousand offshore wind turbines in Europe, causing impairment of production and thus also to the security of supply, exports and productivity of the economy. As noted in the Global Cybersecurity Outlook 2024 by the World Economic Forum, the cybersecurity challenges will continue affecting companies with threats, such as phishing and third-party attacks, and gaps, such as lack of cyber skills within the company, being more present than ever.[32] To tackle these challenges, the Global Cybersecurity Outlook 2024 suggests, is to build on the cybersecurity resilience, evaluating not only the company's internal security capabilities (for example, IT security analytics), but also those of the vendors and partners in the supply chain. Arguably, we can apply similar notions to physical and information security too, claiming that companies will focus on managing and monitoring who has access to what in their business more (for example, biometry and access management in physical premises), as well as have a clear understanding on how security is ensured at the businesses of their partners in the supply chain.

Apart from cybersecurity, adhering to industry-specific regulations and standards (e.g., GDPR, CCPA, ISO 27001) ensures that the supply chain management practices are compliant with the legal and regulatory requirements, reducing the risk of penalties and reputational damage.

6.3 Concluding remarks

Through the classification and given examples, we've tried to draw attention to what's happening in the technology scene and how its developments can be introduced in different industrial sectors. In the Chapter 7, this landscape of advanced technologies is linked with the landscape of supply chain challenges to provide concrete examples how advanced technologies can be used to overcome supply chain challenges.

Further, this landscape of advanced technologies will be used to identify suitable tech-savvy SMEs to participate in the ResC4EU activities (Task 3.3, WP5). Further, it is the basis for defining products and services categories in the envisaged B2B marketplace of the ResC4EU platform and the incorporation of the corresponding NACE codes (Rev. 2.1 Classification of Economic Activities[33]) and the latest ECLASS Release 14.0.[34]

[31] Hackerangriff auf Satelliten legt Steuerung von elf Gigawatt Windkraftanlagen lahm. Retrieved from https://www.pv-magazine.de/2022/03/01/hackerangriff-auf-satelliten-legt-steuerung-von-elf-gigawatt-windkraftanlagen-lahm/ (accessed 29.07.2024)
[32] Global Cybersecurity Outlook 2024. Retrieved from https://www3.weforum.org/docs/WEF_Global_Cybersecurity_Outlook_2024.pdf (accessed on 24.04.2024)
[33] NACE Rev. 2.1 classification is now official. Retrieved from https://ec.europa.eu/eurostat/web/products-eurostat-news/w/wdn-20230210-1 (accessed 7.08.2024)
[34] Enable your global business and digitization. Retrieved from https://eclass.eu/en/ (accessed 7.08.2024)

7 Mapping of Supply Chain Challenges and Advanced Technologies

The two proposed landscapes in the previous chapters – landscape of supply chain challenges of SMEs and landscape of advanced technologies – draw the first insights in what supply chain struggles the companies have and what advanced technologies are out there to solve or minimise these struggles.

With the focus on resilience, sustainability, innovation thinking, as well as climate neutrality making the headlines for the companies, in this chapter we zoom in different business ecosystems and promote some of the best industrial practices or applications.

For the mapping, we've created another framework that: 1) links both landscapes together to showcase different technological scenarios in different supply chain processes and 2) outlines a specific industrial example in relation of this linkage, identified by the ResC4EU project partners through their experience working with the SMEs, for example, from the industry events, company interviews, or previously done survey and reports.

The framework puts the focus on the targeted 14 industrial sectors, as defined in the Annual Single Market Report 2021,[35] namely:

(1) aerospace and defence,
(2) agri-food,
(3) construction,
(4) cultural and creative industries,
(5) digital,
(6) electronics,
(7) energy intensive industries,
(8) energy-renewables,
(9) health,
(10) mobility, transport and automative,
(11) proximity, social economy and civil security,
(12) retail,
(13) textile, and
(14) tourism.

The best practice examples have been provided by the ResC4EU's cluster partners based on the business insights from its member SMEs. The outcome of the mapping is presented in the following sections.

[35] Annual Single Market Report 2021. Retrieved from https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf (accessed 9.07.2024)

7.1 Aerospace and defence: Internal standard and digital twins to relocate production faster

Industry:	Aerospace and defence
Supply chain challenge	Planning and inbound logistics: • Supplier susceptibility to external forces • Supplier dependency risks • Supplier failures Production: • Production process risks (equipment failures) • Quality control issues
Advanced technology:	Data and storage: • Data management and analytics (data virtualisation) • Data governance and backup Security: • Cyber security • Information security Software: • Advanced computing • Modelling (digital twins)

Best practice:

To produce aircraft components, the semi-finished textile products, made of glass fibres or carbon fibres, are required, and they must be supplied in identical and constant quality. For the industry companies it usually means – only the products from the same plant would be supplied causing risks in the planning, inbound logistics, and production processes and resulting in low flexibility and high business dependency on the supplier. An internal standard, that described a comprehensive data set, was developed, making a transfer from one plant or location to another possible. It included that all machine data and quality features were documented and made transferable, as well as the machine settings could also be optimized by means of remote diagnosis and consultation. In case of system or production failure, it meant that relocation to another production site could be done within some days, significantly increasing resilience, flexibility and business continuity.

7.2 Agri-food: Data-driven payment system to go hand in hand with the market

Industry:	Agri-food
Supply chain challenges:	Planning: • Limited resources for data management and demand forecasting • Forecasting inability and ineffective business management • Inadequate resource allocation Outbound logistics: Sales and Distribution:

- No sales strategy
- No data analytics/ management
- False/ imprecise marketing decisions

Advanced technology:

Data and storage:

- Data management and analytics

Security:

- Cyber security
- Information security

Software:

- Artificial intelligence (machine learning)
- Advanced computing (cloud computing)
- Digital platforms

Hardware and materials

- Advanced hardware

Best practice:

Quite often, small agri-food businesses that sell their own production face the challenges in the planning and sales process. Due to the lack of proper data management and analytics and lack of transparent, traceable and forecastable sales activities, the companies struggle to properly understand their market and their needs, as well as quickly adapt to market changes, putting a pressure on their supply and production process. By excluding the ineffective data collection methods (such as hand-written reports, Excel files and photographed receipts) and introducing a **payment system that includes a hardware mobile device and software applications** at their selling stations, the companies gain a thorough understanding of their selling activities and apply analytics to this data to make their stock up-to-date and plan accordingly to market fluctuations. It increases the business flexibility and customer service, as well as builds foundation for further sustainability and resilience.

7.3 Construction: Database to compare and verify construction materials across different standards

Industry: Construction

Supply chain challenges:

Planning:

- Limited resources for strategic procurement

Inbound logistics: procurement and supply:

- Supplier and material quality issues
- Raw material shortages
- Ethical sourcing of raw materials
- Supplier dependency risks

Advanced technology:	Data and storage: • Data management and analytics Software: • Artificial intelligence (machine learning) • Digital platforms

Best practice:

Construction materials are constantly evolving, and it poses different challenges in the planning and even more in the inbound logistics process to address the little or no diversification of sources for raw materials, low quality control measures and low understanding of discrepancies between the EU and non-EU standards. Investing in advanced digital equipment for materials quality testing, the initiative by the Lukasiewicz Research Network - Institute of Ceramics and Building Materials (ICiMB) has developed a comprehensive **database** that facilitates the comparison and verification of materials across different standards. For industry companies, it means a precise identification and alignment with varying regulatory requirements, ensuring that materials meet both local and international standards efficiently, for example, those between the EU and Ukraine. It therefore builds better understanding of the supply market and better relationships with suppliers, as well as works on business risk mitigation and business continuity.

7.4 Cultural and creative industries: Product-applicable technologies to transform the production process

Industry:	Cultural and creative industries
Supply chain challenges:	Production: • Product complexity • Manual work • Time-consuming production • Production process risks due to inappropriate equipment and quality control • High percentage of defective products
Advanced technology:	Hardware: • Advanced hardware (printers, IoT) Software: • Artificial intelligence (Machine learning and Machine vision) • Digital platforms

Best practice:

As no product-applicable printers were available, the company, that produces customisable digital wallpapers, struggled with their production process. Adjusting the advertising printers for their operations, they tackled such challenges as time-consuming production process, constant problems with inappropriate equipment, quality control issues and high percentage of defective products. Upgrading their printers to more advanced and product-applicable **printing technologies**, interlinked with a software programme that oversees and controls all production steps at once, the company automated the manual work, improved

their production speed, and increased the overall product quality. It added to the company's planning and sourcing capabilities, competitive advantage and increased the customer satisfaction, making the whole supply chain much more resilient and effective. [36]

7.5 Digital: Computer management software to increase the security standards in the company

Industry: Digital

Supply chain challenges:

Production:

- Time-consuming process
- Manual work
- High percentage of human errors
- Production process risks in quality control issues
- Power outages

Planning:

- Limited resources for data management

Advanced technology:

Data and storage:

- Data management and analytics
- Storage technologies
- Data governance and backup

Software:

- Advanced computing (cloud computing)
- Digital platforms

Security:

- Cyber security
- Information security

Best practice:

As a telecommunication operator, the company faced different challenges in its production process to ensure their services. Though the company had high security standards for both their equipment (physical, virtual, and reserve servers) and client information, the current process was time-consuming, included manual work and subsequential percentage of human errors, and was open to constant cyber security risks. In addition, the potential power outages put a risk on always providing the services as promised. It resulted in hectic business operations, low customer satisfaction and low data management options for future service and market demand forecasting. The company implemented a **professional computer network management software** that upgraded the firewall management features, improved data monitoring, and allowed the analysis of data for future internal and external risk identification. Through that the company increased the business competitive advantage, gained higher customer satisfaction and retention and made the supply chain processes more resilient.

[36] About Livette's. Retrieved from https://eu.livetteswallpaper.com/pages/about-livettes-wallpaper (accessed 31.07.2024)

7.6 Electronics: Electromechanical device to overcome raw material scarcity and enable local production

Industry:	**Electronics**
Supply chain challenges:	Planning: • Inventory issues • Rising costs • Sudden market changes Inbound logistics: Procurement and Supply: • Raw material shortages • Difficulties in ensuring timely delivery of materials • Supplier dependency risks, such as delays in material delivery
Advanced technology:	Software: • Advanced computing Hardware and materials: • Advanced electronics

Best practice:

In the Covid-19 pandemic, the ventilator production faced the challenges in the planning and inbound logistics processes - due to scarcity of raw materials, there was a need for a proper new design and implementation that includes a rapid and cost-effective production and the use of mainly local suppliers (same region). A prototype was designed: a **controlled electromechanical device** that triggers the contraction of a commercially available manual resuscitator or AMBU (Airway Mask Bag Unit) to provide the adequate **inspiration and expiration for intubated patients,** meeting the specifications, adjusted by the healthcare personnel, for each patient. It ensured the business continuity and flexibility of ventilator production, as well as increased the competitive advantage of the local region.

7.7 Energy intensive industries: Suite of advanced technologies to enhance energy management capabilities

Industry:	**Energy intensive industries**
Supply chain challenges:	Planning: • Limited resources for data management • Forecasting inability • Rising costs Production: • Excessive energy usage • Inadequate process optimisation
Advanced technology:	Hardware and materials: • Advanced hardware (sensors, IoT) Software: • Artificial intelligence (machine learning)

- Advanced computing (cloud computing)
- Digital platforms

Data and storage:

- Data management and analytics

Security:

- Cyber security
- Information security

Best practice:

A manufacturer faced a significant planning and production challenge due to a lack of insight into their energy management and costs. They struggled with tracking energy usage and costs, unable to pinpoint when and where energy was consumed, or identify specific hotspots driving excessive usage. This difficulty extended to recognising energy waste, as there was no clear view of how much energy was used for unproductive activities, hindering their ability to take targeted action. Calculating overheads was equally problematic, with inaccurate estimates of energy consumption by individual assets or products making it hard to justify cost increases to customers amid fluctuating energy prices. Additionally, the manufacturer was unable to identify abnormal activity, remaining unaware of assets consuming excessive energy or showing signs of impending failure, and lacked the means to understand the peak factory load. This compounded the challenge of managing energy efficiency and cost control effectively within their operations.

To address these challenges, the manufacturer implemented a suite of advanced technologies designed to enhance their energy management capabilities. They installed **energy monitoring devices** throughout their facilities to collect real-time data on energy consumption, pinpointing exactly where and when energy was being used. This data was integrated into a **cloud-based software platform**, which centralised the information and provided a comprehensive view of **energy usage across all operations**. Leveraging Internet of Things (IoT) technology, the system continuously monitored and transmitted data from various assets, ensuring up-to-date insights. To further refine their understanding and response, the manufacturer employed **AI models** that analysed patterns in the energy data, identifying inefficiencies, predicting potential issues with equipment, and optimising energy use. This technological integration enabled the manufacturer to accurately track energy hotspots, address wasteful practices, calculate overheads more precisely, and detect abnormal activity before it led to costly downtime, ultimately improving overall energy efficiency and cost management, as well as increased the business continuity and flexibility.

7.8 Energy renewables: Automated inspection technology to monitor the production equipment and enhance the reliability of the process

Industry: Energy renewables

Supply chain challenges: Production:

- Product complexity
- Manual work
- Time-consuming process
- Quality control issues
- High percentage of defective products

Advanced technology:

Data and storage:
- Data management and analytics

Software:
- Artificial intelligence (machine vision, deep learning)
- Advanced computing

Hardware and materials:
- Advanced hardware (robotics, IIoT)

Best practice:

In the production of semiconductor chips, that are significant for the energy renewables technologies and industries, the assembly step is difficult to inspect manually. It leads to quality control issues, potential unnoticed defects and afterwards to increased production costs and delays. To tackle the challenge, the automated inspection technology, that includes robotics and artificial intelligence, can be introduced to monitor the critical production equipment and enhance the reliability and productivity of the process. It results in cost reduction, increased flexibility and higher customer satisfaction.

7.9 Health: Virtual reality to train new employees

Industry: Health

Supply chain challenges:

Planning:
- Labour shortages
- Adapting to remote work
- Rising costs
- Sudden market changes
- Natural disasters and pandemics

Production:
- Product complexity
- Labour shortages
- Time-consuming production
- Production process risks (e.g. closing premises for training)

Advanced technology:

Data and storage:
- Specific data applications, based on VR

Software:
- Virtual reality

Security:
- Cyber security
- Information security

Best practice:

In the catheter assembly setting, training of the new associates required the need to shut down a line, bring new recruits onto the floor, and give them materials that might be scarce in disruptive environments.[37] Especially during and after COVID-19, this planning and production process was also affected by a scarce workforce, employee turnover, and people not coming back to work. All of that took time, money, and components that were very much needed, disrupting the business continuity and decreasing flexibility. With **Virtual Reality (VR)**, the training process was taken away from the floor to a separate training room, or even to employee's home. It resulted in reduced training times and wasted material, increased the employee satisfaction, as well as ensured the business continuity and flexibility.

7.10 Mobility, transport, and automative: Tracking unit to automatically recognise a container accident

Industry:	**Mobility, transport, and automative**
Supply chain challenges:	Outbound logistics: Sales and Distribution: • Transportation delays • Poor coordination and insufficient infrastructure • Transportation accidents
Advanced technology:	Data and storage: • Data management and analytics Hardware and materials: • Advanced hardware (sensors) Software: • Advanced computing • Digital platforms Navigation and connectivity: • Satellite-based navigation systems

Best practice:

According to estimates by the World Shipping Council (WSC), more than 600 containers have been lost in 2022,[38] heavily affecting the logistics processes and resulting in financial, safety and environmental risks. The innovative ConTAD research project[39] tackles the challenge, developing a **tracking unit** for the sea freight containers with the goal to automatically recognise a container accident using condition recognition. It will increase the control and enhance the management of the logistics process, as well as ensure the business continuity and increase the customer satisfaction enhancing the resilience node in the whole supply chain.

[37] Integrating efficiency and fun into VR training. Retrieved from https://www.todaysmedicaldevelopments.com/article/integrating-efficiency-and-fun-into-vr-training-freudenberg-medical/ (accessed 30.07.2024)
[38] World Shipping Council Releases Containers Lost at Sea Report – 2023 Update. Retrieved from https://www.worldshipping.org/news/world-shipping-council-releases-containers-lost-at-sea-report-2023-update (accessed 30.07.2024)
[39] ConTAD. Retrieved from https://www.jade-hs.de/unsere-hochschule/fachbereiche/seefahrt-und-logistik/forschung-praxis/laufende-projekte/contad/ (accessed 30.07.2024)

7.11 Proximity, social economy, and civil security: Route planning system to enable an automated pier-to-pier navigation

Industry: Proximity, social economy, and civil security

Supply chain challenges:

Planning:

- Rising costs
- Limited resources for data management

Outbound logistics: Sales and Distribution:

- Transportation delays
- Poor coordination and insufficient infrastructure
- Transportation accidents

Advanced technology:

Data and storage:

- Data management and analytics

Software:

- Digital platforms

Navigation and connectivity:

- Satellite-based navigation systems

Best practice:

Shipping accidents in the coastal waters and sea regions near the coast always have a high potential to damage the environment and people, causing disruptions in the planning and outbound logistics process. To improve the traffic planning near the coast, the greenCoPilot project[40] aims at developing **a route planning system for ships** that would allow the routes to be planned on-board for automated pier-to-pier navigation. As a result, the companies lower risks of potential accidents, increase the customer satisfaction and ensure the business continuity.

7.12 Retail: B2B digital platforms to find alternative suppliers and logistics services providers

Industry: Retail

Supply chain challenges:

Inbound logistics: Procurement and Supply:

- Raw material shortages
- Difficulties in managing supplier relationships and ensuring timely delivery of materials
- Supplier dependency risks
- Compliance risks
- Supplier failures

Outbound logistics: Sales and Distribution:

- Transportation delays

[40] greenCoPilot: improve traffic planning near the coast. Retrieved from https://www.maritimes-cluster.de/en/topics-and-projects/projects/greencopilot/ (accessed 31.07.2024)

- Poor logistics coordination

Advanced technology:

Data and storage:

- Data management and analytics (data catalogues, data management)

Software:

- Advanced computing (cloud computing- platform as a service)
- Digital platforms

Best practice:

Receiving an order for new type and design cradles, the manufacturer and retailer of furniture for babies faced the procurement and supply challenge in the inbound logistics process, as well as delivery challenge in the outbound logistics process. As their existing suppliers couldn't deliver the specific materials, components and services to reach the necessary customisation and certification, they had to look for the alternatives. The company likewise needed a reliable logistics service to handle the transport of their furniture products. It resulted in decreased flexibility, influenced the business continuity, as well as competitive advantage and customer satisfaction. Starting using a **B2B platform that focuses on the collaboration network for industry, manufacturing, business and logistics in Europe**, the company managed to efficiently find the necessary components and services to complete the order. Specifying the requirements and analysing the data, the company also found the logistics' provider with an expertise in the furniture transportation. It resulted in higher business flexibility and logistics operations, as well as increased customer satisfaction.

7.13 Textile: Advanced inventory management system to monitor the inventory real-time and make proactive adjustments to production schedules

Industry: Textile

Supply chain challenges:

Planning:

- Geopolitical instability and legal framework change- trade regulations
- International trade policy
- Forecasting inability
- Rising costs
- Sudden market changes

Inbound logistics: Procurement and Supply:

- Raw material shortages
- Difficulties in managing supplier relationships and ensuring timely delivery of materials
- Supplier dependency risks
- Compliance risks
- Supplier failures

Advanced technology:

Data and storage:

- Data management and analytics (data management)
- Data governance and backup (data privacy and protection; backup and recovery solutions)

Software:
- Artificial intelligence (machine learning)
- Advanced computing (cloud computing,
- Digital platforms

Security:
- Cyber security
- Information security

Best practice:

Irregular supplies of raw materials, caused by global disruptions, logistics problems, and political decisions (embargoes), have led to production interruptions and increased costs, making it difficult to efficiently run the planning, inbound logistics and production process.

One of the solutions is to implement a strategic stockpiling strategy for critical raw materials and manage the production interruptions and fluctuating supply levels better. By adopting an **advanced inventory management system**, the companies gain the predictive analytics and real-time monitoring tools that enable proactive adjustments to inventory levels and production schedules. It results in a higher risk mitigation, increases sustainability and resilience, as well as ensures the business continuity and flexibility.

7.14 Tourism: Sensors and AI to offer real-time quality control for museum's collection

Industry:	**Tourism**
Supply chain challenges:	Production or service providing: • Labour shortages • Manual work • Time-consuming process • Inadequate process optimisation • Quality control issues • High percentage of errors
Advanced technology:	Data and storage: • Data management and analytics Software: • Artificial intelligence (machine learning) • Advanced computing (cloud computing) • Digital platforms Hardware and materials • Advanced hardware (sensors, IoT)

Best practice:

For museums, serving as important players in the tourism scene, the key challenge is to maintain the quality control for the museum's collection, which is, quite often, still a manual and time-consuming process with a place for high percentage of errors. In rural areas, it likewise goes hand in hand with labour shortages.

The process includes regular walks around the premises, doing the temperature and humidity monitoring to check whether the collection is stored according to specific requirements and regulations, and if done incorrectly or not spotted on time it may significantly damage the collection. Even bigger are the emergencies at night when the damage is only seen in the morning, potentially hours after the temperature and humidity changes. Eventually, it may end up with initiating the damage control to inspect and restore the collection that may also lead to closing the whole museum or section of it to the visitors, therefore losing the customer satisfaction and potential revenues.

By introducing **sensors and software (AI and advanced computing) solution**, the museums can monitor the indoor microclimate digitally: track down the real-time measurements, analyse the metrics for future references, as well as receive notifications in case of anomalies. It makes the service chain more resilient, offering a higher external risk mitigation and operational efficiency, fighting the labour shortages and increasing the overall flexibility.

7.15 Concluding remarks

The mapping celebrates the cross-industry collaboration between the tech and traditional industries, highlighting that innovations, resilience- and sustainability-thinking can be found across all supply chain processes (as we can see the technological advancements can even cover more processes at once, e.g., planning and production), and it lets the SMEs think more about increasing their business flexibility, competitive advantage, and customer satisfaction, as well as work on risk mitigation and business continuity proactively. These best practices likewise outline 2 approaches of tackling the supply chain challenges, giving a wider perspective on where to look for support: 1) the SME itself identifies the challenge and implements the solution; 2) the industry clusters or associations identify the challenge and form a partnership to build a solution. The ResC4EU project will add another approach, offering a portfolio of support for SMEs in finding the solutions.

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