



Manufacturing as a Service for the EU's twin transition until 2040

D2.1 Future of MaaS in Europe: the 2040 vision, trends, scenarios and use cases



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1. Executive summary

"Future of MaaS in Europe: the 2040 vision, trends, scenarios and use cases" is a deliverable linked to WP2 Envisioning & Reframing. The work has been performed as part of the EC funded MASTT2040 (Manufacturing as a Service for the EU's Twin Transition until 2040) strategic foresight project. The deliverable summarizes key outputs, that is: scenario narratives and future use cases and visions of MaaS co-created with stakeholders through structured dialogue and a scenario-building workshop.

This document outlines the methodological assumptions and presents a series of guiding questions that structured discussions on key drivers, trends, weak signals, and potential disruptions during the scenario creation process. The core of the document comprises four distinct scenarios for the future of the European manufacturing sector in 2040,

1. **Designed for Survival** focuses on sustainability amid geopolitical and economic challenges.
2. **Friendshoring** highlights collaboration within Western alliances to counter external pressures and advance circular economy practices.
3. **The Third Pole** reflects Europe's efforts to maintain autonomy amidst US-China rivalry.
4. **Industry 7.5** envisions a Europe-led manufacturing domain powered by advanced AI and localized, eco-conscious production.

The scenarios are presented in two formats: a concise summary and a comprehensive version encompassing key dimensions (political, economic, environmental, societal, technological, and industrial).

The final section analyzes future visions and use cases for MaaS tailored to each scenario, presenting 20 use cases in total. This analysis explores potential future opportunities and risks associated with MaaS in each scenario. These scenarios and use cases will inform the next phases of the MASTT2040 project, guiding discussions for a roadmap and policy recommendations toward a desirable future for MaaS in Europe.

2. Introduction

MASTT2040 (Manufacturing as a Service for the EU's Twin Transition until 2040) is a CSA project, which aims to empower the European manufacturing industry to navigate the complexities of digital transformation and sustainability, with a focus on the "Manufacturing as a Service" (MaaS) model. This model promotes optimised and efficient production processes by offering manufacturing capabilities as on-demand services including instant quotes for those services.

MASTT2040 has two main goals:

- To employ strategic foresight methodologies in an inclusive manner, building a shared understanding of the evolving landscape of MaaS. This involves identifying emerging trends, opportunities, and disruptions, both within and outside the MaaS domain, to inform decision-making and guide the EU manufacturing sector towards a successful twin transition by 2040.
- To actively involve key stakeholders, including those from the MaaS and Circular Economy communities, the manufacturing industry, and standards development organisations. This collaborative effort aims to create a strategic roadmap and action plan with short-term (5 years), medium-term (10 years), and long-term (15 years) perspectives, fostering the advancement of digitalisation, circularity, decarbonisation, and sustainability in industrial production.

MASTT2040 employs a comprehensive participatory foresight approach, ensuring that the project outputs are collectively produced, applicable, and accessible to all stakeholders in the manufacturing domain.

The "Future of MaaS in Europe: the 2040 vision, trends, scenarios and use cases" is a deliverable linked to WP2 Envisioning & Reframing and it summarizes key outputs, that is: scenario narratives and future use cases and visions of MaaS co-created with stakeholders through structured dialogue and a scenario-building workshop.

3. Methodological approach

3.1. Scenarios of European manufacturing: key characteristics and guiding criteria

Prior to scenario development, clear characteristics and criteria to guide the process are established. This ensures the scenarios are high-quality, relevant, and aligned with best practices in scenario research.

The sought for scenario characteristics include the following:

- **Plausible:** Grounded in realistic possibilities, even if they challenge current assumptions.
- **Challenging:** Provocative and thought-provoking, pushing boundaries and sparking debate.
- **Non-Obvious:** Avoiding predictable or conventional outcomes, facilitating the exploration of unexpected possibilities.
- **Distinct:** Offering contrasting visions of the future, highlighting diverse potential pathways.
- **Comprehensive:** Covering a broad spectrum of potential futures, encompassing a range of possibilities.
- **Internally coherent:** Ensuring logical consistency within each scenario, with the various elements aligning in a believable manner.

The following criteria are central to the scenario development process:

- Scenarios describe a wide spectrum of potential futures; their aim is not to endorse a specific direction but to provide a framework for discussion.
- All scenarios should be of equal probability and desirability. This means that no scenario should be presented as more likely or preferable than another, encouraging open-minded consideration of all possibilities.
- Scenarios are simply tools within the process, designed to help create a more future-proof strategy, policy, or organization. This means that scenarios are not predictions or prophecies, but rather tools to explore different possibilities and prepare for a range of potential futures, ultimately helping to make more robust and adaptable strategies.

3.2. Scenario structure and guiding questions

The project team adapted the (G)PESTLEI framework to prepare a scenario form and a set of questions aimed to structure discussion during the scenario building workshop. The scenario form consists of 7 dimensions and linked guiding questions.

Political Context of Manufacturing

- What are the most important political forces driving changes in the manufacturing sector?
- What is the political context in which European manufacturing functions? What is the shape of the EU in this scenario?
- How does it impact the manufacturing sector?
- What is the EU policy vis-à-vis the manufacturing sector? What does the regulation space look like, and what is its impact on businesses?

Economic Context of Manufacturing

- What are the most important economic forces driving changes in the manufacturing sector?
- What does economic international cooperation look like in this scenario? How does it impact the manufacturing sector?
- What's the state of globalisation? What rules does it follow, what is its scope? What's Europe's stance vis-à-vis globalisation? How does it impact the manufacturing sector?
- What is the state of the EU's strategic autonomy? What is its impact on the manufacturing sector? Is the EU reliant on other countries for critical raw materials and technologies?
- What drives the competitiveness of the manufacturing sector? Have any new business models emerged?

Environmental Context of Manufacturing

- What are the most important environmental forces driving changes in the manufacturing sector in this scenario? How do environmental issues impact the economic context of manufacturing in this scenario?
- What is the global progress on climate change adaptation and mitigation? How far has the EU transitioned to a circular economy? How does it impact manufacturing? Are manufacturing processes sustainable?
- How do global supply chains function? How do they impact the manufacturing sector?

- Are there any new environmental regulations? What are they and how do they impact manufacturing?

Social Context of Manufacturing

- What are the most important social forces driving changes in the manufacturing sector?
- What does the labor market look like? What kind of workers and skill sets are needed in the manufacturing sector? What is the ratio between human employment and automatization?
- What are the demographic problems manufacturing faces in such a scenario? Is there a labor shortage?

Technological Context of Manufacturing

- What are the most important technological forces driving changes in the manufacturing sector?
- What does the access to technologies in this scenario look like? Are technologies cheap and available? Is the use of some technologies in the manufacturing sector obstructed in any way?
- What technologies are the most important to the manufacturing sector? Which technologies assure success in manufacturing?
- What are the most important regulations impacting the use of technologies in the manufacturing sector in this scenario?
- What drives innovation in the manufacturing sector?

Industrial Context of Manufacturing

- What are the most important industrial factors in this scenario? To what forces should the manufacturers respond in the first place?
- What kind of factories are successful in this scenario? What kind of factories struggle in this scenario? What is the key to manufacturing success in this scenario?
- What does the cooperation between various manufacturers and manufacturing stakeholders look like? What are the main drivers or blockers of cooperation? What value/feature characterizes various forms of cooperation best?
- What does competition between manufacturers look like in this scenario? Against whom do the European manufacturers compete and how do they do this?
- What does standardisation in European manufacturing look like in this scenario? What is the EU's approach towards green and digital transformation in manufacturing in this scenario?

Forms of manufacturing

- What is the dominant model of manufacturing in this scenario?
- What is the role of centralised and contract manufacturing in this scenario?
- Are there any important niches for other - maybe novel - forms of manufacturing in this scenario?

3.3. Developing MaaS use cases and MaaS vision in the context of each scenario

Before elaborating future MaaS use cases, it is necessary to establish guiding questions, which will then be discussed with the participants of the scenario workshop. These guiding questions aim to explore the potential applications, benefits, challenges, and limitations of the MaaS model within different future scenarios. The insights generated with these questions are expected to help develop a roadmap for the

European manufacturing sector until 2040, aimed to close the strategic gaps the answers to questions will help to reveal.

- How does Manufacturing-as-a-Service fit in this scenario? How does the MaaS model manifest itself in this scenario?
- Are there any particular sectors in which MaaS may be seen as a superior model? Are there any particular sectors in which MaaS may be seen as inferior?
- Are there any particular ways and rules according to which MaaS operates in this scenario? What challenges manufacturers operating under the frames of MaaS model face in this scenario? Are there any opportunities that arise in each scenario for MaaS manufacturers?

Similar guiding questions need to be formulated to guide discussion about preferred vision of MaaS in the context of future scenarios of European manufacturing. These guiding questions aim to explore how the MaaS model can be adapted and leveraged to maximize its positive impact on the manufacturing sector, support the Twin Transition, and enhance EU strategic autonomy within different future scenarios.

- How should the concept of MaaS transform to have a bigger impact on the manufacturing in this scenario? How to ensure MaaS success in this scenario?
- How could MaaS help in achieving the goals of the Twin Transition (green and digital) in this scenario?
- How could MaaS help in building the EU's strategic autonomy in this scenario?

3.4 Organisation of work

For the scenario analysis method to be most effective, the scenarios should ideally be plausible yet challenging. They should aim to challenge not only the current state of affairs but also how the future of a given topic is usually imagined or considered probable, while at the same time remaining realistic enough to be seriously considered for strategic purposes. This can be achieved through a rigorous, multi-phase process:

- **Desk Research:** Consortium members conducted extensive research to identify and analyze trends and signals of change within the manufacturing sector. This resulted in a comprehensive list of trends, subsequently refined into a shortlist, and a catalog of main drivers and signals of change.
- **Expert Evaluation:** Manufacturing experts utilized the 4CF Sprawl tool to assess the shortlisted trends, focusing on their uncertainty and potential disruptions. These insights, combined with the identified signals of change, informed the creation of a list of disruptive events.
- **Delphi Study:** Selected experts evaluated the disruptive events, considering their probability and potential impact on the Twin Transition (the simultaneous pursuit of green and digital goals). This expert input further refined the understanding of potential future scenarios.
- **Scenario outlines creation:** The outcomes of the Delphi Study, encompassing both quantitative rankings and qualitative expert commentary, served as the bedrock for the construction of the scenario outlines. In the selection of the defining factors for each scenario outline, the following guiding criteria should be used:
 - **Emphasis on Uncertainty:** Prioritisation of events that experts deemed uncertain (with probability neither very low nor very high), ensuring that the resultant scenarios would transcend the obvious and challenge conventional thinking. In some instances, similar

disruptions can be strategically clustered to enhance the overall coherence and plausibility of the scenarios.

- **Impact on the Twin Transition:** To ensure that the scenarios are sufficiently challenging, events with a clear and pronounced impact—whether positive or negative—on the Twin Transition should be sought.
 - **Internal Coherence:** Even though the aim should be to develop non-obvious scenarios, special attention should be paid to the selection of events that contribute to the internal consistency and logical cohesion of each scenario, ensuring that the various elements within each narrative align in a believable and compelling manner.
- **Scenario workshop:** the 4-hour workshop took place in Brussels on 25 November 2024. About 40 persons registered and 27 attended the event. Each participant received a detailed agenda (Annex 5.1) and a read-ahead material (Annex 5.2) consisting of: a list of key trends, drivers, disruptions shaping the future of the manufacturing sector as well as the results of the Delphi study and the description of the EU Manufacturing strategy. They were split into 4 working groups, each group was tasked to develop one scenario following the guidelines of facilitators and using scenario working templates¹.
 - **Scenario writing:** The narrations of the scenarios were completed by WP2 lead and sent to the MASTT2040 team for additions and cross-checking.
 - **Formulation of future use cases of MaaS in the context of each scenario:** The final phase of the WP2 involved the identification of hypothetical yet plausible future use-cases of MaaS in the context of twin transformation based on various opportunities that arise in each scenario for MaaS as well as some challenges that MaaS could help overcome. This was done in two phases: i) through a scenario-impact analysis during a scenario workshop and ii) internally by the strategic analysis of the collected insights and formulation of the future use cases and applications.

4. Outputs

4.1. Scenario outlines for the workshop

4.1.1 Scenario outline 1

- China is the world's leading force in manufacturing. It managed to establish a global network of research and innovation centers, attracting top talent from around the world. The US and Europe failed to craft a unified Western policy towards China.
- The manufacturing sector in Europe has become dominated by huge conglomerates providing manufacturing services to smaller enterprises. Essentially, smaller enterprises are outsourcing their production to these giants.
- Consumer demand for hyper-personalized products is much higher than in 2024 which puts an immense pressure on manufacturers. Also, the product-as-a-Service business model is far more

¹ Simplified scenario templates are part of Deliverable 2.2

common and popular among consumers than it was in 2024.

4.1.2 Scenario outline 2

- Friendshoring has become a dominant paradigm in the West. The US and European Union managed to create a united political front against China.
- Collaborative production ecosystems have become commonplace in Europe.
- The use of AI leads to democratisation of manufacturing by providing easily available new solutions and applications available to a wide array of actors, including SMEs. Additionally, data processing has progressed so rapidly and so far that it facilitated establishment of fully transparent supply chains and autonomous logistics. An international data exchange platform with standardized protocols, allowing seamless and secure data sharing between businesses and individuals was established.

4.1.3 Scenario outline 3

- The global political and economical rivalry between the United States and China puts a pressure on the European Union to adapt. Both actors are more innovative than the European states.
- The pace of technological development, also in terms of Artificial Intelligence, is uneven around the world. The adoption of new technologies slowed down also due to widespread and destructive cyber attacks.
- The newly-introduced EU policy facilitated the establishment of a network of "hyper-flexible factories" that can rapidly reconfigure their production lines to manufacture a wide range of goods, allowing the bloc to quickly respond to supply chain disruptions and changing market demands. To foster innovativeness, the EU prioritized creativity, arts & culture to make way for new business models.

4.1.4 Scenario outline 4

- The EU is a leading force in manufacturing.
- Due to an immense pace of progress, Artificial Intelligence is far more advanced than in 2024 - it is on a brink of becoming Artificial General Intelligence (AGI). This facilitated many changes impacting manufacturing, such as the development of a breakthrough energy storage technology, enabling efficient and cost-effective storage of renewable energy. Additionally, hyper-advanced autonomous robots are widely used in the manufacturing sector.
- Because of the fact that consumers are much more environmentally conscious than in 2024, their demand for personalized products is low. As a result, the manufacturing processes are increasingly localised and dependent on remanufacturing.

4.2. Final scenarios of European manufacturing in 2040

4.2.1. Scenario 1: Designed for Survival: Europe's quest for sustainability in a changing world

Europe turns to sustainable design and remanufacturing to compete in a world where China dominates manufacturing and democracy is under threat.

- China dominates global manufacturing, attracting top talent and driving trends like hyper-personalization and product-as-a-service.
- The US and Europe struggle to cooperate, and democracy is under pressure, particularly from BRICS countries.
- Europe, facing pressure from China's dominance, focuses on sustainable design and remanufacturing to compete, becoming a design and product-service center.
- The EU invests heavily in chip technology and design platforms while also developing flexible and additive manufacturing.
- Climate change accelerates, resources become scarce, and Europe faces an aging population.
- Flexible and additive manufacturing grow, but traditional forms remain dominant; MaaS spreads in Europe.

4.2.2 Scenario 2: Friendshoring: The West's united front against a rising tide

The US and Europe forge a "friendshoring" alliance to build a sustainable, circular economy and counter China's rise in a deglobalized world.

- The US and EU form a strong alliance ("friendshoring") to counter China's influence and foster collaborative production in Europe. A modern "cold war" emerges, dividing the world between democratic and autocratic powers, leading to further deglobalization.
- AI democratizes manufacturing, supply chains become transparent, and autonomous logistics are established.
- The West builds a circular economy, invests in sustainable mining, and develops cross-ocean ecological transport due to the severe negative effects of climate change.
- Universal Basic Income (UBI) is implemented in the West, funded by taxing AI and automation.
- Distributed manufacturing prevails; integration of autonomization, decentralization, customization, and specialization.

4.2.3 Scenario 3: The Third Pole: Europe navigating the crosscurrents of US-China rivalry

Amidst US-China rivalry, a divided Europe struggles to maintain autonomy by prioritizing local production, hyper-flexible factories, and a creative economy.

- The US and China engage in fierce rivalry, while the EU strives for autonomy ("third pole") and navigates between them.
- To maintain autonomy, the EU establishes a network of "hyper-flexible factories" to adapt to disruptions and changing demands.
- The EU, dealing with US-China rivalry and seeking to foster innovativeness, prioritizes local capabilities, regional development, and a creative economy (emphasizing arts and culture).

- Internal political tensions and nationalistic sentiments challenge the EU's unity.
- The EU maintains a strong commitment to environmental sustainability and circular manufacturing principles.
- Hyper-flexible factories; MaaS gains traction; SMEs and cooperatives play a vital role.

4.2.4 Scenario 4: Industry 7.5: Europe's leadership in the age of advanced AI

A unified Europe leads global manufacturing in a world transformed by advanced AI, robotics, and environmentally conscious consumers, with a focus on localized production and bio-based materials.

- A politically unified EU leads global manufacturing, driven by advancements in AI (approaching AGI) and robotics.
- Breakthrough energy storage technology enables the use of renewable energy.
- Consumers are environmentally conscious, leading to localized manufacturing, remanufacturing, and increased reliance on bio-based materials.
- The EU standardizes components for global trade, and its regulatory frameworks gain international influence.
- Labor unions, now more coordinated across the EU, advocate for improved social safety nets (like UBI) to address the impact of AGI and automation.
- Additive manufacturing leads to localized repair; contract manufacturing dominates due to DPPs and open marketplaces.

4.3. Full scenario narratives

4.3.1 Scenario 1 - Designed for Survival: Europe's quest for sustainability in a changing world

In 2040, the world of manufacturing is dominated by China which managed to establish a global network of research and innovation centers, attracting top talent from around the world. As a consequence, some manufacturing trends, visible already in 2024, had been strengthened. Consumers around the world are much more insistent on hyper-personalized products which puts a pressure on manufacturers. The product-as-a-service model is far more common and popular with consumers than in 2024.

What fostered China's position even more, was the fact that the US and Europe failed to craft a united Western policy towards the state. Democracy faces increasing pressure, especially from BRICS countries, and the European Union is at a risk of disintegration. Such unfavorable political and economic conditions forced a deep transformation of European manufacturing. Though it is much weaker globally, the sector does its best to compete, looking for its competitive advantage in sustainable design.

Political Context of Manufacturing

- Cooperation between the US and the EU is challenging and transactional - both actors cooperate when their interests come hand in hand, yet they are unable to form a unified and solid policy based on Western values.
- Democracy faces a dual threat: the growing influence of BRICS countries and the destabilizing effects of deepening inequality, reaching levels far beyond those seen in 2024.
- Europe pursues strategic partnerships with India and African countries, seeking both to counterbalance China's influence and to secure alternative sources of raw materials.

Economic Context of Manufacturing

- The EU has invested heavily in its manufacturing sector, particularly in design capabilities.
- Remanufacturing is a distinct feature of European industry, supported by a shift towards product-service provision.

Environmental Context of Manufacturing

- Climate change has accelerated significantly since 2024, leading to a global surge in extreme weather events and their devastating consequences. This has fueled political instability, further exacerbated by mass climate migration.
- Countries around the world deal with water and energy scarcity. Access to raw materials is also limited.
- Despite the urgent need to address negative impacts of climate change, industry lobbying often weakens European environmental policies.

Social Context of Manufacturing

- The world, including Europe, deals with an aging population. As a result, global businesses compete heavily for young and qualified immigrants.
- The EU has increased investment in lifelong learning initiatives. European education systems have undergone reforms to address the needs of increasingly diverse societies, with a focus on collaboration. The EU has funded educational programs promoting creativity in various fields (culture, arts, literature and gaming etc.) and increased its focus on intellectual property rights and recycling.

Technological Context of Manufacturing

- The European Union invested heavily in chips technology, fostering design skills and building design platforms.
- The European Union has successfully integrated flexible and additive manufacturing into its industrial landscape. This integration is characterized by increased interconnectivity, including standardized data exchange, contributing to both competitiveness and sustainability

Industrial Landscape and Manufacturing Trends

- China's globally dominant position in manufacturing, as well as consumers' demands, put a high pressure on European manufacturers. The growing presence of Chinese manufacturing companies in Europe reflects their continuous efforts to better understand customer needs.
- Threat coming from Chinese companies forced a remaking of the European manufacturing sector. It is now dominated by huge conglomerates providing manufacturing services to smaller enterprises, including SMEs.
- Flexible and additive manufacturing are much more popular than in 2024.
- Traditional forms of manufacturing - centralised and contracted - are dominant around the world with China's industry ecosystem transforming to adapt to new trends.
- The EU's strategic decisions in terms of manufacturing - betting on remanufacturing, sustainable and modular design, widespread adoption of Digital Product Passports, transformation into a product-service provider - resulted in a much wider spread of manufacturing-as-a-service model in Europe.

4.3.2 Scenario 2 - Friendshoring: The West's united front against a rising tide

In 2040, the world of manufacturing can be best described by the sole word - friendshoring. The US and the European Union, having forged a strong political alliance, have successfully created a unified political front against China. This united front, underpinned by shared values, has fostered a thriving ecosystem of collaborative production in Europe.

Advancements in AI have democratized manufacturing, making innovative solutions and applications accessible to all, including SMEs. Additionally, unprecedented progress in data processing has enabled the establishment of fully transparent supply chains and autonomous logistics. The creation of an international data exchange platform with standardized protocols has further facilitated seamless and secure data sharing.

Political Context of Manufacturing

- There's a fierce global competition between the West and its adversaries. As a result, the world is stuck in a modern "cold war", being divided between democratic and autocratic powers.
- In face of this global rivalry, the United States and the European Union managed to establish a strong cooperation. Not only have they put the paradigm of friendshoring in practice, but they have also designed common policies to counter the political and economical influence of their adversaries.

Economic Context of Manufacturing

- Political rivalry heavily influenced the world economic order, resulting in further deglobalisation. Political strains limit international economic cooperation, forcing countries to prioritize partnerships with like-minded countries.
- The US and the EU managed to deepen their economic integration. They established one internal market which drives manufacturing open-connected. Utilising the G7 format, they also worked out a joint economic offer of cooperation directed at the Global South.

- Unfavorable economic circumstances resulted in the “degrowth” ideology's rising popularity, especially in the West.

Environmental Context of Manufacturing

- The progressing climate change heavily influenced industrial and economic policy-making in the West. The EU and the US managed to build a circular economy. They have also developed urban and sustainable mining and invested heavily in cross ocean ecological transport.
- In the West, environmental regulations are balanced with a voluntary approach - this especially refers to standards of cooperation with the Global South.
- Due to severe negative effects of climate change, sustainability became a top priority around the world.

Social Context of Manufacturing

- In the West, the implementation of a universal basic income (UBI) has been made possible by the taxation of Artificial Intelligence and automation, providing citizens with a financial safety net to cover their essential needs.
- People who want to earn more than UBI need to work, usually in highly specialized jobs. This contributed to growing economic and skills inequalities among Western societies.
- Despite automation, there's a continuous demand for highly skilled workers. Companies compete on the job market by offering them various opportunities, such as sophisticated lifelong learning programs.
- Western countries have invested much in basic fundamental research as a way to foster disruptive ideas and increase their standing in global economic competition.

Technological Context of Manufacturing

- The world experiences rapid progress on new technologies, especially Artificial Intelligence. The progress has been utilized, especially in the West, to increase the autonomy and sustainability of manufacturing processes.
- Circular technologies for remanufacturing cycles are widely available. Digital twins are also commonly used.
- The United States and the European Union managed to establish an interoperable and open technological environment which served the goal of deepening their economic integration.

Industrial Landscape and Manufacturing Trends

- Flexibility at different levels of operations - both in the ecosystem, and in companies - is the main factor guaranteeing market success.
- Transparent supply chains and autonomous logistics facilitated the establishment of collaborative manufacturing ecosystems. Technological progress also helped in a widespread adoption of modular production.
- The West faces challenges in accessing raw materials. Manufacturers and policymakers are addressing this through substantial investments in engineering and technology.
- In Western countries, distributed manufacturing has become a popular production model. The most successful forms of manufacturing are those that integrate autonomization, decentralization, customization, and specialization. Additionally, dynamic collaborative production ecosystems offer significant value by enabling entrepreneurs and manufacturers to optimize production flow.

4.3.3 Scenario 3 - The Third Pole: Europe navigating the crosscurrents of US-China rivalry

In 2040, the globe is feeling the pressure from political and economic rivalry between the United States and China. Two superpowers compete fiercely for the status of the world's No. 1 in every area - from innovation to manufacturing. Their rivalry, together with widespread and destructive cyber attacks, is one of the reasons why the pace of technological development and adoption of new technologies, also in terms of Artificial Intelligence, is uneven around the world.

The European Union, despite internal tensions, tries to keep an equal distance from the two, positioning itself as a "third pole", safeguarding its own interests and autonomy. One instrument to achieve this is a new industrial policy in which the bloc policy facilitated the establishment of a network of "hyper-flexible factories" that can rapidly reconfigure their production lines to manufacture a wide range of goods, allowing them to quickly respond to supply chain disruptions and changing market demands. Additionally, to foster innovation, the EU prioritized creativity, arts, and culture to make way for new business models.

Political Context of Manufacturing

- The EU exists within a complex geopolitical landscape, positioned between two dominant powers. The bloc seeks to avoid being perceived as adversarial by either the US or China and maintains a distance from both.
- The EU experiences internal political tensions and a resurgence of nationalistic sentiments. These internal divisions further complicate the bloc's ability to present a unified front on the global stage. The EU still prioritises strategic autonomy and self-reliance, but internal divisions limit the effectiveness of its policy.

Economic Context of Manufacturing

- US and China rivalry influences trade patterns and creates a degree of economic uncertainty - the EU trades with both parties, from time to time experiencing hardships tied to trade war(s) between the two.
- The EU's strategy emphasizes leveraging local capabilities and resources rather than specializing in specific products. This approach aims to promote regional economic development and reduce dependence on external supply chains.
- The EU fosters a creative economy by recognizing the potential of arts and culture to drive innovation and economic growth. This emphasis on creativity supports the development of new business models and enhances the region's competitiveness.

Environmental Context of Manufacturing

- Continuous push on environmental issues is one of the most important factors differentiating EU from the US or China. The EU maintains its strong commitment to environmental sustainability, with a continued emphasis on decarbonization efforts and the promotion of sustainable manufacturing practices.
- The EU actively promotes the adoption of circular manufacturing principles, aiming to minimize waste and maximize resource efficiency. This includes initiatives to encourage recycling, reuse, and remanufacturing within the manufacturing sector.

Social Context of Manufacturing

- To distribute economic opportunities more evenly among European societies and revitalize rural communities, the EU puts a strong emphasis on place-based production, extending beyond urban centers.
- To increase social acceptance for the EU, the bloc adopted hyper-flexible factories - they contribute to low unemployment rates, providing greater economic stability and social well-being.
- The EU's insistence on creativity, arts & culture offers European societies the opportunity to focus on other developmental ideas. The notion of degrowth gains popularity.

Technological Context of Manufacturing

- In face of uneven technological progress around the world, the EU adopts a pragmatic approach, prioritizing accessible and affordable technologies that can be readily implemented across various regions and industries.
- The EU establishes a secure and standardized digital infrastructure for data exchange and collaboration within its manufacturing network. This facilitates efficient communication and cooperation among various actors, also aiming to limit the negative effects of cyberattacks.

Industrial Landscape and Manufacturing Trends

- The EU's industrial landscape is characterized by a network of interconnected hyper-flexible factories. These factories offer the benefits of rapid reconfiguration and adaptability, enabling efficient responses to market demands and supply chain disruptions.
- While the network of hyper-flexible factories presents opportunities for collaboration and efficiency, there is also a degree of skepticism and competition among manufacturers within the network. Some companies are hesitant to fully participate due to concerns about sharing proprietary information and maintaining their competitive edge. Some internal tensions in the EU also contribute to this distrust.
- European manufacturing is increasingly driven by local needs and demands. This focus on local production and consumption aligns with the EU's emphasis on regional economic development and self-sufficiency.
- The EU's capability to compete globally in the manufacturing sector is limited by strong positions of the US and China who effectively utilize different forms of manufacturing, such as revamped centralised model (modernised thanks to the use of new technologies) or contracted manufacturing.
- In Europe, the manufacturing-as-a-service model gains traction, offering greater flexibility and customization to businesses. This model aligns well with the EU's network of hyper-flexible factories, enabling efficient production and delivery of customized products.
- Small and medium-sized enterprises (SMEs) play a vital role in European manufacturing. Additionally, community-led cooperatives emerge as important players, fostering local production and consumption.

4.3.4 Scenario 4 - Industry 7.5: Europe's leadership in the age of advanced AI

In 2040, the manufacturing landscape is characterized by a politically unified European Union, taking on a leading role in global manufacturing. Advancements in AI, nearing Artificial General Intelligence (AGI), have revolutionized the industry. A breakthrough energy storage technology has been developed, enabling efficient and cost-effective storage of renewable energy. Hyper-advanced autonomous robots, still a dream in 2024, are widely used in the manufacturing sector.

In such a technologically advanced world one could expect manufacturing to be omnipresent, focused on hyper-personalization and heavy utilisation of the remaining resources. Yet, surprisingly, the world of manufacturing is quite different, owing mostly to the fact that the consumers are much more environmentally conscious. As a result, the manufacturing processes are increasingly localised and dependent on remanufacturing.

Political Context of Manufacturing

- The European Union has achieved a higher level of political unification, with increased collaboration and integration among its member states.
- With the United States and China focusing their economic and political attention on other sectors, the European Union emerges as a dominant force in global manufacturing. This leadership position allows the EU to shape and influence global manufacturing trends and policies.
- The EU's regulatory frameworks, standards, and best practices for manufacturing gain international recognition and influence. Other countries and regions may adopt or adapt these frameworks, further solidifying the EU's leadership in the sector.
- International relations and interregional discussions are shaped by the complex interplay between political protectionism and collaboration. While some countries may adopt protectionist measures to safeguard their domestic industries, others may seek collaboration and partnerships to enhance their manufacturing capabilities.

Economic Context of Manufacturing

- The EU's leadership in manufacturing leads to a broad standardization of components, facilitating seamless global trade and collaboration. This standardization creates a more efficient and interconnected global marketplace.
- As other markets align with EU standards, the bloc's economic influence and competitiveness increase. This alignment fosters greater economic integration and interdependence.
- Despite advancements in technology and collaboration, the ownership and control of materials and components remain largely within the hands of original equipment manufacturers (OEMs) and designers. This concentration of ownership limits the potential for public or consumer-driven material wealth generation.

Environmental Context of Manufacturing

- While the challenges associated with global warming have been largely addressed, the focus shifts to other environmental impacts. There's a growing emphasis on considering factors like human health within a comprehensive Life Cycle Assessment (LCA) framework.
- Technological advancements have led to the development of abundant and carbon-neutral energy sources.
- The increased demand for bio-based materials creates tensions and conflicts over land use. There's a need to balance the production of feedstock for these materials with the preservation of biodiversity and natural ecosystems.

Social Context of Manufacturing

- Advancements in AI, particularly in language translation, foster a stronger sense of European identity and reduce language barriers. This facilitates greater cultural exchange and collaboration within the EU.
- The widespread use of automation and advanced robotics leads to a significant transformation of the labor market. Traditional manufacturing jobs become increasingly scarce, requiring workers to adapt and acquire new skills. The workforce focuses on essential skills that complement advanced technologies. These skills include managing regulatory frameworks, applying human creativity in design and eco-design, conducting research and development, and managing raw materials.
- Labor unions and workers' organizations, as well as their actions, become more coordinated across the EU. They advocate for improved social safety nets, such as a Universal Basic Income (UBI), to address the potential impact of AGI and automation on employment.

Technological Context of Manufacturing

- Manufacturing processes are heavily reliant on advanced robotics, including humanoid robots, for increased efficiency and precision.
- There's a strong emphasis on technological innovations as well as on utilizing organic and locally sourced materials, reducing dependence on critical raw materials and minimizing environmental impact.
- The focus is on developing and implementing technologies that are readily available and affordable.

Industrial Landscape and Manufacturing Trends

- The main factors driving competitiveness are sustainability, exceptional customer service, and the effective utilization of metadata. Companies that prioritize these aspects are likely to be the most efficient.
- The increased emphasis on data sharing and transparency creates numerous opportunities for collaboration and innovation within the manufacturing ecosystem. Companies can leverage shared data and insights to develop new products, optimize processes, and improve efficiency.
- With the rise of additive manufacturing, repair businesses become increasingly localized and household-based. This allows for on-demand repair services and reduces the need for shipping and transportation.
- Marketplaces for materials, components, and processes become more prevalent. These marketplaces are underpinned by Digital Product Passports (DPPs), ensuring transparency and traceability throughout the product lifecycle.
- The combination of DPPs and open marketplaces leads to a dominance of contract manufacturing models. Companies can easily source materials and components from various suppliers and contract manufacturers for production.

4.3.5 Scenarios of European manufacturing in 2040: the comparison

Category	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Geopolitical Dynamics	US-EU cooperation weak; democracy under pressure from BRICS	US-EU alliance ("friendshoring") counters China; "cold war"	US-China rivalry; EU as "third pole"; internal EU tensions	EU leads in manufacturing; US and China focus elsewhere; political protectionism vs. collaboration
Technological Advancements	Focus on sustainable design, flexible and additive manufacturing, chip technology	AI democratizes manufacturing; transparent supply chains; autonomous logistics	Hyper-flexible factories; pragmatic approach to technology adoption	AI approaching AGI; advanced robotics; breakthrough energy storage
Economic Structure	China dominates; EU focuses on design and product-service; large conglomerates emerge	Further deglobalization; Western circular economy; UBI	EU emphasizes local capabilities and creative economy	EU standardization; localized repair businesses; marketplaces with Digital Product Passports
Environmental Focus	Climate change intensifies; resource scarcity	Western emphasis on sustainability; cross-ocean ecological transport	Continued EU commitment to sustainability and circularity	Environmentally conscious consumers; localized production; bio-based materials; focus on broader environmental impacts
Social Changes	Aging population; competition for immigrants; EU invests in lifelong learning	UBI in the West; growing inequality; focus on highly skilled workers	Hyper-flexible factories aim for social acceptance; degrowth gains popularity	Stronger European identity; labor market transformation; focus on essential skills; labor unions advocate for social safety nets
Dominant Manufacturing Models	Flexible and additive manufacturing grow, but traditional forms remain dominant; MaaS spreads in Europe	Distributed manufacturing prevails; integration of autonomization, decentralization, customization, and specialization	Hyper-flexible factories; MaaS gains traction; SMEs and cooperatives play a vital role	Additive manufacturing leads to localized repair; contract manufacturing dominates due to

				DPPs and open marketplaces
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4.4 Visions and use cases of MaaS across scenarios

The development of use cases for Manufacturing as a Service (MaaS) was guided by a stepwise process to explore plausible applications within four future scenarios of European manufacturing for 2040. The use cases are not aimed at as predictions but tools to help companies and policymakers anticipate future trends and opportunities. The process integrates insights from scenario building workshop, review of industry practices, and literature to provide a comprehensive foundation for strategic planning. Importantly, these use cases are not meant to be retrospectively evaluated for accuracy but to enable proactive adaptation and preparation for potential futures.

Step 1. Delineating use cases

The scenario-building workshop generated input on how use cases for manufacturing fit within four distinct 2040 scenarios. This included exploring how use cases could operate, the opportunities MaaS manufacturers could leverage, the challenges they might face within the frames of the MaaS model, and key aspects to ensure success.

These initial insights were further enriched by:

- The finalized descriptions of the four scenarios for industrial manufacturing in 2040, supported by a PESTLE analysis performed for each scenario.
- The casebook, “Current State of MaaS Approaches and Best Practices to Advance the CE”, which detailed the current state of MaaS approaches, major themes for MaaS services, archetype business models, and real-world examples from industry.
- An in-depth analysis of sources from the literature study, providing additional perspectives on the current and emerging trends in MaaS.

By integrating these sources, a comprehensive list of use-case opportunities was developed for each scenario, reflecting plausible applications and opportunities for MaaS in the future.

Step 2. Describing use cases by integrating opportunities

For each of the four scenarios, five distinct use cases were developed. These use cases combined different opportunities identified in Step 1 to illustrate how MaaS could evolve and operate in 2040. Each use case was designed to reflect some of the unique characteristics of its scenario, offering actionable examples of how MaaS services might function in different future contexts.

Step 3. Analysis of the 20 use cases

Each of the 20 use cases supporting digital and green were developed and analysed. This included:

- The identification of possible services that could be offered within the use case.

- An assessment of the risks associated with the realization of the use case.

The next sections describe the use cases with examples of services. Afterwards a structured overview of the risks associated with their realization is provided, grouped logically based on themes. ChatGPT was used to enhance the readability and style of writing the descriptions for the use cases.

4.4.1 Future use cases of MaaS in scenario 1

Use Case: Dynamic ecosystems for circular manufacturing

Europe emerges as a global leader in sustainable and efficient manufacturing, driven by dynamic ecosystems that integrate advanced technologies and collaboration. These platforms connect customers with manufacturers, enabling flexible, on-demand production of personalized products. AI-driven design services empower customers to co-create unique products that align with their needs and sustainability goals. Additionally, in the product lifecycle platforms dynamically connect customers to repair and remanufacturing providers through automated smart contracts.

Digital Product Passports (DPPs) provide transparency and traceability, granting access to lifecycle data to optimize manufacturing within R-cycles. SMEs collaborate through decentralized hubs, sharing resources, tools, and expertise to offer sustainable production, repair, and remanufacturing as a service. Regional hubs host open-access equipment libraries with pay-per-use and subscription models, reducing barriers for SMEs and startups. Digital inventory providers, material banks, and OEMs streamline resource allocation by storing and redistributing spare parts and recovered components or enabling their on-demand local production. This ecosystem fosters innovation, sustainability, and resource efficiency in a competitive manufacturing environment.

Examples of services

- **On-demand manufacturing platforms:** On-demand manufacturing platforms provide customers access to modular production units that can be reconfigured dynamically for different products or processes.
- **Real-time digital twin to adjust production:** Digital twins monitor production lines and simulate reconfiguration scenarios.
- **Platform for manufacturer collaboration:** A platform services connect stakeholders across the supply chain to support i.e. equipment sharing, resource allocation, process optimization, and collaboration in on-demand production.
- **Localized and sustainable production:** The network supports decentralized manufacturing, enabling SMEs to collaborate with hyper-flexible factories to meet regional needs while reducing logistics emissions. Digital Product Passports (DPPs) ensure lifecycle transparency and sustainability compliance.
- **Customization and customer-driven manufacturing:** The platform allows manufacturers to quickly pivot to produce highly customized goods in response to specific consumer demands. Virtual prototyping environments facilitate rapid design iterations and consumer feedback integration.

Use Case: Digital trade hubs for a Circular Economy

Digital trade hubs powered form the backbone of Europe's circular economy, enabling the dynamic reuse of materials and remanufacture of products. These platforms connect surplus and unused materials, components, and equipment with real-time production demands, reducing waste and enhancing sustainability. Digital trade hubs integrate materials banks, surplus-aware networks, and digital inventories to optimize resource allocation and foster collaboration among SMEs and larger manufacturers.

The hubs act as marketplaces where manufacturers can trade remanufactured components and recycled materials at lower costs while meeting stringent sustainability standards. Blockchain-enabled traceability and AI-powered matchmaking systems ensure transparent, efficient, and secure transactions. Manufacturers actively contribute to this shared economy model by making surplus and unused resources available through these platforms. AI-driven Digital Product Passports (DPPs) track the lifecycle of materials and components, ensuring compliance with circular economy standards and building trust among stakeholders. Modular kits and on-demand remanufacturing solutions further enhance resource efficiency, supporting Europe's commitment to sustainability and resource independence.

Examples of services

- **Dynamic material allocation platforms:** AI-driven systems predict and allocate surplus and unused materials across manufacturers based on real-time production needs.
- **Blockchain-verified Digital Product Passports:** DPPs improve traceability, enhance transparency in transactions, and streamline circular economy compliance.
- **Manufacturing as a Service kits:** On-demand platforms offer SMEs access to modular manufacturing kits tailored to specific production requirements. Recovered and remanufactured components from trade hubs are integrated into modular manufacturing solutions.
- **Materials banks and surplus-aware platforms:** Centralized repositories store surplus materials, spare parts, and recovered components for redistribution. Surplus-aware networks track unused resources within companies, connecting them with manufacturers who need them.
- **Buyer-supplier matchmaking:** AI algorithms of platforms match buyers and suppliers on trade hubs, considering factors such as resource availability, proximity, and compliance with standards. Advanced simulations optimize trade decisions to minimize costs and environmental impacts.

Use Case: Equipment-as-a-Service Ecosystems

Adaptive Equipment-as-a-Service (EaaS) ecosystems have become central to Europe's sustainable manufacturing landscape. These ecosystems provide manufacturers with flexible access to modular production equipment, infrastructure, and digitized services. Advanced AI-enabled platforms and cloud-based systems remotely optimize operations, manage predictive maintenance, and guide real-time upgrades to ensure equipment longevity and adaptability. EaaS models offer tailored solutions, from availability-based services to success-driven collaborations, enabling manufacturers to align operational costs with desired outcomes such as efficiency, quality, and sustainability.

This servitization of production equipment has transformed how SMEs and large manufacturers innovate and collaborate. By eliminating the financial burden of equipment ownership and supporting resource-sharing models, EaaS enhances flexibility, reduces waste, and promotes sustainable practices. Digital twins and

digital product passports provide transparency across the lifecycle, while modular upgrades ensure equipment evolves with technological advancements, extending its usability and value.

Examples of services

- **On-demand access to modular equipment:** Modular equipment libraries provide flexible access to specialized tools and infrastructure tailored to production needs. AI-driven platforms recommend optimal equipment configurations, ensuring efficient resource utilization.
- **Cloud-enabled operations management:** AI and IoT monitor equipment performance in real time, optimizing processes and identifying inefficiencies. Predictive maintenance systems ensure maximum uptime, while automated diagnostics reduce downtime.
- **Lifecycle transparency through digital product passports:** DPPs track equipment usage, maintenance, and upgrades, providing a comprehensive lifecycle overview. They ensure compliance with circular economy principles by monitoring material recovery and reuse.
- **Tailored EaaS models for flexible engagement:** Services support scalable solutions aligned with manufacturer-specific needs and goals: availability-, utilization-, results- and economic success-based models.
- **Dynamic equipment upgrades and refurbishments:** Modular upgrades and refurbishments ensure equipment adapts to technological advancements and evolving production requirements. Remote deployment of software upgrades and hardware enhancements extends equipment life.

Use Case: Localized energy integration

Localized energy platforms enable energy-sharing networks, ensuring operational continuity amidst energy scarcity. This empowers SMEs to maintain sustainability and resilience in the face of resource constraints. These hubs integrate seamlessly with MaaS platforms to dynamically share energy among manufacturers based on real-time production demands and resource availability. This approach reduces dependency on centralized energy grids and fossil fuels while ensuring continuity during energy shortages or supply chain disruptions. Localized renewable energy storage solutions also mitigate the risks of fluctuating power availability, providing SMEs with an uninterrupted and sustainable energy supply.

These renewable hubs foster collaboration between energy providers and manufacturers through subscription-based energy-sharing networks. SMEs can access clean energy tailored to their specific operational needs without the burden of upfront capital investment. The integration of predictive AI ensures that energy usage is optimized across manufacturing networks, reducing carbon emissions and operational inefficiencies.

Examples of services

- **Access to local, renewable energy:** Subscription models offer access to localized renewable energy solutions. They ensure consistent power supply on a pay-as-you-use basis.
- **Energy sharing networks:** Platforms dynamically allocate renewable energy based on real-time demand and availability.
- **Predictive energy management:** AI-powered platforms analyze production schedules, weather forecasts, and real-time energy data to optimize energy allocation and usage across manufacturing networks. Manufacturers receive recommendations on the most efficient energy consumption patterns to reduce costs and emissions.

- **Peer-to-peer energy trading platforms:** Decentralized energy trading platforms allow manufacturers to securely buy and sell excess renewable energy within localized networks.
- **Energy demand forecasting and flexibility services:** Digital twins and AI-driven tools forecast future energy demands across manufacturing networks and provide manufacturers with options for flexible energy loads to adjust production schedules.
- **Resilience-as-a-Service:** SMEs can subscribe to resilience solutions that ensure operational continuity during power disruptions. These include backup microgrid services, automated energy switching, and dynamic load balancing tailored to SME production processes.

Use Case: AI-augmented workforce

Wearable AI technologies transform the manufacturing workforce by addressing the challenges of an aging population and evolving job requirements. These devices enhance worker productivity and safety by providing real-time assistance tailored to individual needs. Ergonomic sensors monitor worker posture, offering immediate feedback to reduce fatigue and prevent injuries. Simultaneously, AI algorithms guide workers through complex tasks, ensuring precision and consistency in operations. Sensors continuously monitor workers' vital signs and alert them to potential hazards in their environment. The result is a workforce empowered by technology enable services, capable of sustaining high productivity levels while mitigating the physical challenges associated with labor-intensive roles.

Examples of services

- **Ergonomic and cognitive load management systems:** Wearables equipped with AI analyze workers' mental and physical fatigue in real-time. They enable to dynamically adjust workflows, suggest rest periods, or provide cognitive aids like step-by-step augmented reality guidance for complex processes. Devices continuously monitor and alert workers and supervisors to potential health risks.
- **Skill augmentation:** Embedded AR/VR devices provide real-time, hands-free skill augmentation, enabling workers to perform tasks beyond their current expertise. These devices overlay instructions, best practices, and AI-driven optimization for machinery handling or repair tasks. They train operators on the job.
- **Exoskeleton integration:** AI-integrated exoskeletons provide real-time support for heavy lifting, repetitive movements, or prolonged standing. The exoskeletons adapt dynamically to workers' movements, reducing strain and enhancing physical endurance during intensive manufacturing tasks.
- **Personalized productivity insights:** AI wearables gather data on individual worker performance (e.g., movement efficiency, task completion time) and generate tailored insights to improve productivity. Subscription platforms provide personalized recommendations to optimize performance and reduce fatigue.
- **Collaborative workflow coordination:** Based on sensor data, AI platforms optimize team workflows and dynamically reallocates resources or provides task reassignment.
- **Digital twins for workforce optimization:** Digital twins simulate workers' physical and cognitive performance in manufacturing environments. AI-insights derived from these simulations enable companies to design safer workflows, equipment layouts, and task assignments.

4.4.2 Future use cases of MaaS in scenario 2

Use Case: Across ocean distributed manufacturing network

A resilient distributed manufacturing network based on a collaborative open federated platform for manufacturing is central to the US-EU friendshoring alliance. The platform ensures secure, sustainable, and transparent supply chains by connecting manufacturing hubs across allied nations. Leveraging advanced AI and blockchain, the network fosters cross-border collaboration while enabling a circular economy.

This platform prioritizes interoperability through shared open standards, allowing seamless integration of regional manufacturing nodes. Opportunities are provided for developers to integrate innovative microservices, enhancing functionality across the network. Peer-to-peer communication between participants is a core feature, enabling decentralized collaboration. As the ecosystem evolves, the scalable framework integrates a large number of participants and advanced technologies, fostering a secure environment that builds trust among stakeholders.

Examples of services

- **Cross-ocean circular manufacturing:** AI-services enable sharing production capacity and shorten supply chains across transatlantic hubs. The DPP supported services facilitate collaborative, transparent production processes while minimizing environmental impact. AI predicts demand patterns to optimize production allocation and supports localized production for on-demand manufacturing.
- **AI-powered manufacturing marketplaces:** Marketplaces dynamically match production demands with available capacities, connecting participants through peer-to-peer communication channels for seamless collaboration. Integrated microservices provide real-time analytics, matchmaking, and workflow automation.
- **Sustainable Raw Material Exchange:** A marketplace allows manufacturers to share availability of critical raw materials, with secure peer-to-peer exchanges ensuring transparency and trust. Microservices provide lifecycle tracking and material sourcing insights.
- **Digital Product Passports (DPPs) for lifecycle tracing:** DPPs provide real-time data on sustainability metrics for each product, including carbon footprints and material origins across the supply chain. Microservices enable advanced analytics and reporting, ensuring transparency and regulatory compliance.
- **Developer ecosystem for microservices:** Open APIs of manufacturing platforms foster a developer-friendly environment where innovators can deploy microservices for monitoring, optimization, and analytics. This ensures constant technological evolution and integration of cutting-edge capabilities.

Use Case: Circular urban mining networks

Circular urban mining networks reclaim (rare) materials and components from electronic waste and discarded products, transforming them into valuable resources for manufacturing. Decentralized processing hubs across Europe and the US, connected through MaaS platforms, employ advanced AI and robotics to efficiently sort, extract, and repurpose materials while minimizing waste. Shared data spaces enable transparent tracking of recovered materials, ensuring they meet sustainability and quality standards for reintegration into manufacturing.

Material banks play a pivotal role by storing and redistributing recovered materials and components, ensuring their availability for reuse in manufacturing. Digital Product Passports (DPPs) provide comprehensive information on material composition and product lifecycles, enabling precision in urban mining and supporting compliance with circular economy goals. This approach reduces dependency on traditional mining, retains embedded energy and materials, and fosters sustainable manufacturing processes.

Examples of services

- **Smart waste processing:** Urban mining hubs equipped with AI and robotics process electronic waste, recovering rare materials and reusable components.
- **Material banks for recovered resources:** Material banks serve as centralized repositories for storing and redistributing recovered, qualitative materials and components. AI-services ensure that reclaimed qualitative materials are accessible to manufacturers across the network, facilitating seamless reintegration into production.
- **Digital Product Passports (DPPs) for product and materials tracing:** DPP services provide detailed information about material composition, product lifecycles, and sustainability metrics, enabling precision urban mining and compliance with environmental regulations.
- **Recovery and reuse services:** The network enables repair and remanufacturing processes to recover components at their highest value. These recovered components are reintroduced into the manufacturing cycle via material banks, reducing waste and conserving energy.

Use Case: Zero-waste certification programs

Zero-waste certification programs incentivize manufacturers to adopt circular economy practices by certifying products and processes that achieve minimal waste. These programs are powered by MaaS platforms and supported by a marketplace ecosystem that promotes the development and integration of microservices. These microservices offer tools for detailed sustainability assessments, process optimization, lifecycle tracking, and certification compliance. Providers of microservices play a key role by delivering specialized solutions tailored to manufacturers' needs.

Digital Product and Process Passports enhance the traceability and transparency of resources, enabling certification bodies to verify compliance with zero-waste standards effectively. They promote collaboration among manufacturers, recyclers, and certification bodies to ensure the traceability and reuse of resources. This use case not only fosters sustainable practices but also supports other manufacturing use cases by providing lifecycle insights and sustainability services that benefit diverse production processes.

Examples of services

- **Sustainability assessment tools:** Platforms use AI to evaluate the environmental impact of manufacturing processes and suggest optimizations.
- **Lifecycle tracking services:** Blockchain-based Digital Product and Process Passports systems trace materials and processes from production to end-of-life, providing transparency, data for certification for compliance and enabling process optimization.

- **Marketplace-orchestrated microservices:** Marketplace APIs promote and facilitate the integration of microservices developed by third-party providers. These microservices include waste tracking, material reuse optimization, and real-time analytics to support zero-waste initiatives.
- **Cross-use case services:** The zero-waste certification services provide sustainability and lifecycle data that can be utilized by other manufacturing use cases, such as repair and remanufacturing, urban mining networks, and hyper-flexible production. These shared insights enhance the overall efficiency of interconnected use cases.

Use Case: Distributed manufacturing networks

Hubs for additive manufacturing (AM) and other rapid manufacturing technologies proliferate across Europe and the US, enabling localized and distributed production. Initially focused on producing parts, these hubs are transitioning to produce complete products tailored to customers needs made up of multiple components and manufacturing technologies. Connected through MaaS platforms, these hubs provide SMEs with access to shared equipment, materials, and modular production capabilities. The decentralized approach minimizes transportation costs and emissions by producing parts closer to their points of use, aligning with sustainability goals and enhancing supply chain resilience.

AI-powered systems manage hub operations, optimizing resource allocation and production processes across regions. Providers of AI-enabled microservices facilitate knowledge sharing, automating key processes such as quotation, Design for Manufacturing (DFM) analysis, optimal process parameter definition, and production program creation, supported by real-time simulations. Design support services leverage the unique capabilities of manufacturing technologies and accelerate product development for customers. These services reduce reliance on experts and streamline workflows. Autonomous and optimized logistics systems ensure sustainable transportation of parts and products to customers. These networks enable manufacturers to respond quickly to changes in demand, disruptions, or market needs while fostering sustainability and strategic autonomy.

Examples of services

- **Shared additive and rapid manufacturing facilities:** The hub offers SMEs access to advanced AM equipment, raw materials, and software for localized production. Platform services coordinate these assets, enabling seamless scheduling and resource sharing.
- **Modular and rapid manufacturing capabilities:** Hubs provide modular production lines capable of being reconfigured quickly to adapt to changes in demand or product specifications. Microservice providers contribute optimization tools for rapid reconfiguration.
- **Sustainable and autonomous optimized logistics:** Integrated logistics systems coordinate the transport of parts and products from hubs in the supply chain and to customers. AI-services ensure efficient routing and minimal environmental impact.
- **Marketplace for microservices:** A marketplace connects hubs with providers of microservices, offering tools for manufacturability analysis, sustainability impact analysis, quality assurance, supply chain optimization, and design support. Microservice providers play a key role in ensuring continuous improvement and scalability of the network.

Use Case: Dynamic labor support systems

Dynamic labor support systems integrate human-machine collaboration within manufacturing networks, balancing roles based on real-time needs. These systems leverage AI to allocate tasks between humans and robots, ensuring optimal productivity, cost-efficiency, and adaptability to market demands. MaaS platforms provide on-demand access to both skilled labor and autonomous systems, allowing manufacturers to scale operations dynamically.

Production equipment providers and integrators play a key role by offering state-of-the-art production equipment, and equipment-as-a-service (EaaS) models. This enables manufacturers to access advanced systems without large upfront investments. Services integrating in-depth manufacturing knowledge reduce the need for highly skilled workers. Labor unions collaborate with manufacturers to define ethical guidelines, ensuring fair treatment in hybrid machine-operator environments. These systems help SMEs and larger manufacturers adapt to fluctuating demands while maintaining quality and sustainability.

Examples of services

- **AI-driven workforce training:** Services provide real-time, adaptive training modules for workers based on their interaction with machines, ensuring skill development for hybrid human-robot environments.
- **Task automation analytics:** Platforms analyze production workflows to identify tasks suitable for automation. AI tools help manufacturers prioritize and implement cost-effective automation solutions while balancing human-machine roles.
- **Dynamic safety monitoring:** Wearables and sensors monitor the safety of human workers collaborating with robots. AI systems provide real-time alerts to avoid collisions and reduce workplace hazards.
- **Labor and equipment performance dashboards:** AI platforms track and analyze the performance of both human workers and robotic systems. Insights help optimize task assignments, enhance productivity, and identify areas for operational improvement.
- **Ethical labor management services:** Platforms support labor unions and manufacturers in defining and monitoring ethical guidelines, ensuring fair workload distribution, safe conditions, and equitable treatment in hybrid work environments.

4.4.3 Future use cases of MaaS in scenario 3

Use Case: A hyper-flexible manufacturing network

A hyper-flexible manufacturing network interlinks flexible factories, larger factories, SMEs, and cooperatives into a decentralized and adaptable ecosystem. Supply chains and production lines of factories can be reconfigured within hours to meet fluctuating demand, mitigate supply chain disruptions, and align with evolving consumer preferences. Modular factory designs allow for scalability, specialization, and customization within a company.

MaaS platforms enable on-demand production in a local, adaptive manufacturing network. They ensure seamless communication and collaboration among manufacturers, suppliers, and logistics providers. MaaS

platforms connect participants, enabling reconfiguration and optimized resource usage. This supports regional sustainable production and reduces dependency on global supply chains.

Examples of services

- **Access to modular production units:** Platforms provide access to modular production units that can be reconfigured dynamically for different products or processes. Services integrate real-time production planning and automated programming of production technologies and modular equipment configurations.
- **Real-time digital twin to adjust production:** Digital twins monitor production lines and simulate reconfiguration scenarios in the factory and supply chain to ensure efficient utilization of resources and adjust production schedules.
- **Platform for manufacturer connectivity and collaboration:** A platform connects manufacturers, suppliers, and logistics providers across the supply chain. This platform enables equipment sharing, resource allocation, and process optimization, and on-demand production. The platform also supports data sharing to synchronize operations across the production network.
- **Resource sharing and equipment optimization:** Platform services coordinate shared resources, including equipment, tools, and raw materials. They ensure optimal use of resources across the network and reduce idle time and waste.
- **Localized, sustainable production:** Platform services enable SMEs to quickly find and collaborate with flexible factories in local production networks. They meet regional needs, reduce logistics, and ensure with Digital Product Passports transparency and sustainability compliance.
- **Customization and customer-driven manufacturing:** Platform services support manufacturers to quickly pivot to produce highly customized goods in response to specific consumer demands. Virtual prototyping environments facilitate rapid design iterations and consumer feedback integration.

Use Case: Resilient, self-healing supply chains

Europe develops resilient supply chains that autonomously detect and resolve disruptions using AI-powered platforms. AI-enabled systems analyze real-time data from sensors and digital twins across the supply chain, supporting reroute logistics, reallocating resources, and adjusting production schedules when disruptions occur. This capability ensures resilience in the face of global supply chain instability caused by geopolitical tensions, natural disasters, and market fluctuations.

Collaboration among local, European manufacturers and access to local on-demand manufacturing networks enable flexible, rapid responses to disruptions and increase independence from the US and China. Equipment-as-a-Service (EaaS) providers remotely manage and rapidly heal production system to mitigate possible production failures. Digital inventories provide access to all necessary information, ensuring IP compliance, and supporting compatibility with original product specifications.

Examples of services

- **Disruption management:** AI-powered systems detect and respond to supply chain disruptions by rerouting logistics, reallocating materials, and adjusting production schedules.

- **Predictive analytics platforms:** These platforms use real-time data from sensors and digital twins, along with historical data, to predict disruptions before they occur. Predictive tools provide manufacturers and logistics providers with actionable insights, allowing proactive adjustments.
- **Equipment-as-a-Service (EaaS):** EaaS provides manufacturers access to remote monitoring services, rapid repair or equipment upgrades. In case of failure or capacity shortage EaaS platforms provide access to shared or rented equipment from nearby facilities.
- **Local on-demand manufacturing networks:** Access to on-demand manufacturing networks within Europe enables manufacturers to produce critical components locally during supply chain disruptions. These networks leverage modular production systems and shared facilities to quickly adapt to changing needs. Collaboration between manufacturers ensures that production capacity is maximized and redundancies are avoided.
- **Digital inventories:** Digital inventories provide access to all required product and manufacturing information to support high-quality production. To protect intellectual property, digital inventories include encryption and access controls, allowing manufacturers to share designs securely and comply with IP.

Use Case: Local additive and on-demand manufacturing networks

Local additive and on-demand manufacturing networks are a cornerstone of Europe's production ecosystem. MaaS platforms connect regional micro-factories and SMEs, enabling on-demand distributed production of high-value, customized goods. They are able of a sustainable on-demand production of new products and repair and remanufacturing within R-cycles of the circular economy.

AI-enabled online design, quotation and order services offer easy-to-use solutions to design products, generate CAD models and detailed product specifications tailored for the production processes, and on-demand production with short lead times. Manufacturing platforms facilitate on-demand production and connect manufacturers within local product networks, ensuring efficient collaboration and optimal use of resources. Micro-services provide on-the-spot access to expert knowledge ensuring product quality and first-time-right production. By promoting collaboration among SMEs and larger manufacturers, localized networks enhance Europe's autonomy, competitiveness, and resilience in high-value niche markets.

Examples of services

- **AM equipment rental platforms:** SMEs access shared AM equipment, reducing capital investment and promoting collaboration.
- **Circular AM services:** Platforms support recycling of materials and remanufacturing of products, closing the loop in production.
- **Micro-manufacturing services:** AI-enabled services include simulations, materials science expertise, and manufacturing process optimization tailored to SMEs. By integrating them in marketplaces, developers can rapidly scale their service offer.
- **AI-enables online design, quotation, and order services:** Users can upload concepts, receive AI-enhanced design recommendations, generate cost-effective quotations, and place production orders seamlessly. The services accelerate the product lifecycle from concept to delivery, ensuring short lead times and high customization.

- **Equipment rental and sharing:** Platforms provide services for renting and sharing equipment. They reduce the need for large capital investments for access to advanced production technology.
- **On-demand manufacturing platforms:** These platforms connect SMEs and larger manufacturers within localized product networks. Services coordinate production schedules, resource sharing, and logistics to enable seamless on-demand production. They enable peer to peer communication between companies in the network.
- **R-cycle services:** On-demand platforms, material banks and services integrate circular economy practices, and support repair, remanufacturing, and recycling of components.

Use Case: Cyber-resilient manufacturing networks

Europe's manufacturing sector thrives on cyber-resilient manufacturing networks that integrate advanced cybersecurity measures to protect interconnected ecosystems from cyberattacks. These networks provide robust cybersecurity services to participants, fostering trust and ensuring data integrity and operational continuity.

The secure environment of open manufacturing networks has attracted larger organizations, SMEs, scaleups, and startups, driving the development of diverse services. With secure, open and affordable platforms and data spaces at the core, AI democratizes manufacturing, supply chains become fully transparent, and autonomous logistics are seamlessly integrated. These networks form the foundation of a competitive and resilient manufacturing ecosystem that ensures Europe's leadership in a complex geopolitical landscape.

Examples of services

- **Threat detection platforms:** Continuous AI-based monitoring systems identify and mitigate cyber threats in real time, using machine learning algorithms to adapt to evolving risks. These platforms ensure factories can operate securely while maintaining uninterrupted production processes.
- **Data encryption and secure communication services:** Platforms establish secure, encrypted channels for data exchange among manufacturers, suppliers, and partners. This service guarantees the integrity of shared designs, production schedules, and supply chain data.
- **Cybersecurity-as-a-Service for SMEs and startups:** Tailored cybersecurity services provide smaller players with affordable access to state-of-the-art threat prevention tools, compliance frameworks, and training. This service ensures inclusivity and reduces vulnerability across the network.
- **Autonomous cyber incident response systems:** AI-enabled systems detect and respond to cyber incidents autonomously, minimizing downtime and damage. For example, if a ransomware attack is detected, the system isolates affected areas and deploys backup protocols to ensure operational continuity.
- **Data spaces for secure collaboration and IP protection:** Data spaces facilitate controlled and secure data sharing within manufacturing networks, ensuring compliance with IP regulations, ownership and usage rights.
- **Broad range of data-driven services for platform integration:** Platforms offer a wide array of data-driven services, enabling advanced analytics, predictive maintenance, production optimization, demand forecasting, and resource planning. These services leverage data from factories, suppliers, and logistics providers to optimize manufacturing workflows.

Use Case: Consumer-directed production networks

Europe pioneers consumer-directed production networks that empower customers to directly influence manufacturing through MaaS platforms. These platforms enable consumers to personalize, customize, and order products tailored to their preferences. Advanced product configurators and design tools provide intuitive interfaces for product creation, allowing consumers to co-create designs with manufacturers. Customers can also choose to start with recycled materials and components, promoting sustainability.

Products are produced on-demand in distributed manufacturing facilities near the customer, leveraging hyper-flexible factories that minimize logistics complexity and environmental impact. Throughout the process, consumers are provided with complete transparency, including details on customization, production, delivery, and the sustainability impact of their choices. This approach aligns with Europe's focus on localism and sustainability, enhancing customer satisfaction, reducing waste, and differentiating Europe's manufacturing capabilities from mass production models in the US and China.

Examples of services

- **Product configurator and co-creation tools:** Intuitive configurators allow consumers to design and customize products, offering real-time previews and sustainability insights. Co-creation tools enable direct collaboration between consumers and manufacturers, with AI providing design recommendations and feasibility analysis. For example, a customer designing a custom piece of furniture can adjust materials, dimensions, and aesthetics while receiving feedback on the product's environmental footprint.
- **On-demand production scheduling:** AI-powered systems optimize factory schedules based on consumer orders, ensuring efficient use of resources and timely delivery. These systems balance workload distribution across local hyper-flexible factories, minimizing idle time and maximizing productivity.
- **Distributed manufacturing near the customer:** Distributed manufacturing networks produce goods locally, reducing the carbon footprint associated with long-distance shipping. For instance, a customized product ordered in a European city is manufactured at the nearest micro-factory, ensuring fast delivery and reduced logistics costs.
- **Transparency services across the production lifecycle:** Platforms provide consumers with real-time visibility into the entire production lifecycle, from design and customization to production and delivery. Sustainability dashboards offer insights into the environmental impact of chosen materials, production processes, and logistics. For example, consumers can view the carbon emissions saved by choosing recycled components.
- **Sustainability-driven material selection:** Platforms offer consumers the choice to start with recycled materials and components, highlighting their environmental benefits. For instance, a customer designing electronics can opt for recycled casings and refurbished internal components, reducing demand for virgin materials.

4.4.4 Future use cases of MaaS in scenario 4

Use Case: AI-orchestrated production ecosystems

Europe revolutionizes manufacturing with AI-orchestrated production ecosystems, where factories, equipment, and supply chains autonomously collaborate. These ecosystems leverage advanced AI platforms to integrate manufacturing operations into dynamic, self-optimizing networks. Unlike traditional linear production models, these ecosystems adapt in real time to changes in demand, resource availability, and sustainability goals. Equipment, processes, and logistics systems act as interconnected agents, exchanging data to maximize efficiency and minimize environmental impact.

OEM (Original Equipment Manufacturer) product developers benefit from streamlined collaboration with manufacturing ecosystems, enabling faster prototyping, adaptive production, and enhanced feedback loops for product lifecycle management. AI-supported design services provide OEMs with powerful tools to integrate application-specific requirements and manufacturing constraints into product designs from the outset. By refining their designs OEMs can develop optimized, innovative, and sustainable products tailored to market, application and operational realities.

Examples of services

- **AI-driven process orchestration platforms:** Advanced AI platforms manage and synchronize production systems, including machinery, supply chains, and human resources. OEM product developers gain the ability to monitor manufacturing constraints and directly adjust designs for efficient production. For example, if production bottlenecks occur due to material shortages, OEMs can revise product configurations in collaboration with the manufacturing ecosystem.
- **Interconnected digital twin ecosystems:** Digital twins of production facilities, supply chains, and equipment enable real-time monitoring and simulation. OEMs use these MaaS services to simulate and validate product manufacturability, identify potential issues, and optimize design choices before committing to production. This minimizes costly redesigns and accelerates time-to-market.
- **Predictive resource allocation services:** AI-powered systems forecast material, energy, and labor needs based on market trends, order patterns, and sustainability goals. OEMs can align product designs with available resources, ensuring seamless production without delays. This capability also helps OEMs innovate within sustainable resource constraints, supporting circular economy goals.
- **AI-supported design services:** Design services enable OEMs integrate application and manufacturing knowledge to generate optimized designs. This assures optimized, efficient, and sustainable products and reduces the complexity, material, and energy usage of their production.

Use Case: Bio-inspired modular factories

Bio-inspired modular factories autonomously adapt configurations of facilities based on real-time production needs. These factories utilize bio-inspired components and advanced robotics to dynamically reconfigure themselves, enabling on-demand production and rapid adaptation to market changes. Equipment and infrastructure are designed to integrate seamlessly into these adaptive environments, creating flexibility and efficiency.

This modular approach not only enhances efficiency but also supports sustainability by using bio-based materials and minimizing waste. These factories leverage AI-driven MaaS platforms to coordinate production

schedules, optimize resource allocation, and ensure operational continuity, placing Europe at the forefront of sustainable and innovative manufacturing.

Examples of services

- **Adaptive configuration services:** AI-powered platforms enable factories to autonomously reconfigure layouts, machinery, and workflows in response to real-time production demands. This ensures maximum flexibility and efficiency in meeting shifting market needs.
- **AI-driven resource allocation:** Services analyze real-time production data to dynamically optimize the allocation of resources, including materials, energy, and workforce. This minimizes waste, enhances efficiency, and supports sustainability goals.
- **Sustainability simulation services:** AI-driven digital twins simulate the environmental and operational performance of modular factory configurations. These insights help manufacturers optimize production layouts, reduce carbon footprints, and improve resource efficiency.
- **Bio-based resource optimization:** Platforms manage and monitor the use of bioengineered materials within the factory ecosystem, ensuring minimal resource waste while maximizing the sustainability of production processes.
- **Factory performance monitoring:** Embedded sensors continuously track the performance of modular equipment and components. The collected data provides insights into predictive maintenance needs, operational efficiency, and resource usage, ensuring smooth production continuity.

Use Case: Sustainability metrics

Near-AGI systems revolutionize sustainability by generating dynamic environmental impact metrics that guide manufacturing decisions in real-time. These systems evaluate the environmental footprint of production processes, materials, and logistics, providing actionable recommendations to optimize sustainability.

Real-time metric services are integrated into MaaS platforms, enabling manufacturers to dynamically adjust operations and leverage AI-supported Material Banks for sustainability, resource reuse and recycling. The metrics encompass resource usage, emissions, energy efficiency, and waste management, enabling manufacturers to align with evolving environmental regulations and market demands. Tool developers and service providers play critical roles in designing, implementing, and maintaining systems that ensure seamless integration of sustainability metrics into manufacturing workflows.

The approach fosters transparency and accountability, ensuring Europe's leadership in sustainable manufacturing practices.

Examples of services

- **Environmental impact analysis tools:** AI platforms evaluate and report the sustainability of manufacturing activities, offering real-time recommendations for improvement. Tools analyze data from factories, supply chains, and material banks to provide insights into energy consumption, material waste, and emissions. Tools highlight inefficiencies in production lines and suggest switching to more sustainable solutions. Precision monitoring devices feed accurate data into these systems.

- **Dynamic process adjustment platforms:** These platforms integrate sustainability metrics into production workflows, automatically adjusting parameters to minimize environmental impact. For instance, a platform might reduce energy usage during non-peak hours or reconfigure manufacturing schedules to align with green energy availability. Service providers ensure that these systems are customized and optimized for specific industries, providing ongoing support and upgrades. By integrating data from material banks, these platforms also prioritize the use of recycled and reusable resources, ensuring a circular approach to production.
- **AI-supported material banks:** Material banks act as online platforms storing, managing, and providing access to materials, components and resources for reuse and recycling. Integrated with sustainability metrics, these AI-driven systems enable factories to source no longer used, recycled or remanufactured materials and components aligned with their environmental goals. AI enhances the efficiency of these banks by predicting demand and materials, predicting when components will become available, and ensuring the optimal allocation of resources across factories.

Use Case: Autonomous regional repair hubs

Autonomous regional repair hubs transform Europe's approach to product lifecycle management. These hubs use advanced AI, robotics, and additive manufacturing to repair and remanufacture products locally, extending their lifecycles and reducing waste. Digital product passports and digital inventories store product specifications, and repair guidelines, ensuring compatibility with original products while safeguarding intellectual property. Consumers and businesses benefit from faster turnaround times and reduced costs compared to traditional replacement models. Platforms provide access to needed materials and components, ensuring that repair hubs and affiliated facilities are well-equipped.

To empower SMEs and individuals to participate in the remanufacturing ecosystem, comprehensive training programs are delivered through online and in-person modules, covering technical skills, safety protocols, and best practices. These programs leverage MaaS platforms for knowledge dissemination and real-time support. Europe's right to repair policies ensures access to essential repair manuals, diagnostics, and replacement components, fostering a circular economy and reinforcing sustainability. Platforms also provide centralized access to materials and components through material banks and digital inventories, fostering a circular economy and reinforcing sustainability.

Examples of services

- **Repair coordination platforms:** Platforms manage repair requests, matching them with regional hubs or SMEs best suited for the task. AI evaluates the complexity, urgency, and location of the repair, ensuring efficient workflows. The platform allocates the required parts and materials to the nearest capable facility.
- **Additive manufacturing for repairs:** Hubs use additive manufacturing to produce replacement parts on demand, minimizing waste and inventory costs. This MaaS service ensures compatibility with the original product specifications while enabling customization to meet specific needs. By connecting with the platform, SMEs and repair cafés gain access to these capabilities, either by ordering parts or partnering with hubs for advanced repairs.
- **Training and certification services:** Platforms provide structured training programs for SMEs and individuals, enabling them to perform remanufacturing tasks. Modules include technical skills for

advanced repairs, handling of additive manufacturing equipment, and safety protocols. Certification programs ensure consistent quality and safety standards across all participating entities, building consumer trust in localized repair services.

- **Digital inventories for IP and compatibility assurance:** Digital inventories store detailed product specifications, repair instructions, and IP-protected design files provided by manufacturers. Integrated with MaaS platforms, these inventories ensure that all repairs and remanufacturing activities align with the original product's specifications. They verify compatibility and enforce IP compliance, reducing the risk of substandard repairs or unauthorized use of designs. Manufacturers benefit from controlled access to their IP while repair hubs gain confidence in the quality and precision of their repairs.
- **Material and component access platforms:** MaaS platforms integrate AI-supported material banks and digital inventories to ensure seamless access to required components and materials for repair. These platforms allow to source recycled or remanufactured parts or to obtain them quickly via a digital inventory reducing delays and costs.

Use Case: Embedded sensors for environmental impact monitoring

Products embedded with advanced sensors continuously monitor their usage and environmental impact, feeding real-time data into digital product passports and manufacturing ecosystems. The integration of sensor data into DPPs provides insights into a product's energy consumption, material degradation, and overall lifecycle performance.

Platforms and online services aggregate and analyze this data, providing actionable recommendations for improving product design, operational efficiency, R-cycles and end-of-life management. The combined use of sensors and DPPs fosters transparency and accountability, empowering consumers and stakeholders with accessible, trustworthy environmental data.

Examples of services

- **Sensor data integration platforms:** Platforms collect and analyze environmental data from embedded sensors, providing actionable recommendations to dynamically adjust energy efficiency, reduce emissions, and minimize waste. AI-driven insights enable real-time adjustments, lowering operational costs and environmental impacts.
- **Predictive maintenance insights:** Sensor data detects early signs of material degradation, energy inefficiencies, or component failure. Platforms use AI-driven analysis to generate predictive maintenance schedules, helping manufacturers extend product life, reduce resource consumption, and avoid unplanned downtime.
- **Lifecycle simulation services:** Real-time sensor data integrates with digital twins to simulate product performance across diverse scenarios. These simulations optimize product design, material choices, and lifecycle management strategies, improving sustainability while enhancing operational efficiency.
- **Circular Economy optimization services:** Sensors identify when products or components reach the end of their functional life. Platforms analyze recoverable components and materials, enabling optimal reuse, remanufacturing, and recycling processes. Sensor-driven insights streamline reverse logistics and resource recovery.

- **Environmental compliance assurance services:** Embedded sensors monitor emissions, energy efficiency, and material usage, ensuring regulatory compliance. Platforms generate automated reports and certifications, integrating environmental metrics into digital product passports across the supply chain to optimize sustainability performance.

4.4.5 Overview of future risks

The analysis concluded by identifying risks associated with the 2040 MaaS use cases. This initial risk assessment produced a comprehensive list of potential risks for each use case. Duplicate or overlapping risks were then removed, and similar risks were merged to eliminate redundancy. Finally, the remaining risks were categorized by common themes. After categorizing the risks, their titles and descriptions were refined for clarity and brevity. Risks within each category were then ordered by their potential impact, with related risks grouped together.

Risk category	Description
Cybersecurity and Data Risks	<p>Cybersecurity threats: Increased reliance on digital infrastructure exposes systems to cyberattacks and data breaches.</p> <p>Rapid cyber threat evolution: Sophistication of cyberattacks may outpace current detection and response measures.</p> <p>Data security risks: Sharing sensitive operational data across platforms may lead to privacy breaches or IP theft.</p> <p>IP protection risks: Unauthorized access to shared platforms may result in intellectual property infringement.</p> <p>Privacy concerns: Potential misuse of sensor data or wearable technology could compromise worker or consumer privacy.</p> <p>Data accuracy issues: Errors in sensor data, digital twins, or AI algorithms could lead to poor decisions and inefficiencies.</p>
Technological Adoption and Costs	<p>High initial costs: Significant upfront investment in advanced technologies, platforms, and infrastructure may deter SMEs.</p> <p>Adoption costs: Transitioning to new models, like zero-waste practices or EaaS, may require heavy investment.</p> <p>Technological adoption barriers: SMEs may struggle to adopt advanced tools due to costs, complexity, or lack of support.</p> <p>Skill gaps: The workforce may lack the technical skills needed to use advanced systems, despite training efforts.</p> <p>Resistance to change: Workers or manufacturers may resist adopting new technologies, fearing job displacement or disruption.</p>
AI and Automation Risks	<p>Over-reliance on AI: Dependence on AI systems may cause vulnerabilities if they fail to adapt or produce incorrect outputs.</p>

	<p>Ethical challenges: Automation and AI could exacerbate workforce inequalities or unsafe labor practices.</p>
<p>Integration and Standardization Challenges</p>	<p>Interoperability challenges: Ensuring seamless integration across diverse platforms, systems, and equipment requires significant effort.</p> <p>Standardization issues: Harmonizing processes, equipment compatibility, and data formats across regions remains challenging.</p> <p>Coordination complexity: Managing decentralized hubs, workflows, and stakeholders may require robust governance systems.</p> <p>Logistical complexity: Coordinating distributed production and ensuring timely delivery requires advanced planning.</p> <p>Market dominance: Large players may dominate platforms, sidelining SMEs or restricting fair competition.</p> <p>Operational dependency: Over-reliance on providers or platforms may lead to lock-in or reduced control for manufacturers.</p>
<p>Resource and quality concerns</p>	<p>Resource shortages: Ensuring steady availability of renewable energy, recycled materials, or bioengineered components may be challenging.</p> <p>Dependency on renewable energy: Energy shortages or disruptions during peak demands could impact production continuity.</p> <p>Quality assurance: Recovered materials or modular components may face resistance due to perceived quality inconsistencies.</p>
<p>Consumer and Market Risks</p>	<p>Loose of customer contact: Reliance on digital marketplaces may limit direct relationships with customers and partners.</p> <p>Consumer education gaps: Consumers may lack understanding of tools like configurators or sustainability metrics.</p>

5. Annexes

5.1. Scenario workshop invitation



Invitation

Scenario workshop: *Future(s) of European Manufacturing*

In person event: *25 November 2024 (1:00 - 5:00 pm)*



Source: Images generated with Google Gemini

The Workshop in a Nutshell

The future of manufacturing has been the subject of many reports over the past few years. These reports consider the impact of automation and the development of artificial intelligence systems, as well as the impact of new business models on the environment and the implications of these factors for the labour market.

In this workshop, we will discuss the future of manufacturing with a specific focus on the EU. To encourage long-term thinking, we will adopt a 2040 timeframe for our scenario development process. This will allow stakeholders to envision a range of plausible yet challenging trajectories for the development of manufacturing in Europe.

Workshop participants will develop scenarios to facilitate discussion of Twin Transition goals and the role that manufacturing as a service (MaaS) might play in achieving them. These scenarios will provide a basis for strategic planning and decision-making that considers changes spanning over two decades.

Design of the Workshop

Our dialogue on the future of manufacturing in Europe in 2040 will be framed by preliminary development projections generated by the project team prior to the workshop. These projections, based on previous project results, include a list of key trends, drivers, and weak signals shaping the future of

manufacturing. They cover a wide range of insights: from social to technological, economic, environmental, geopolitical and regulatory issues.

Through structured discussions and group exercises in the spirit of collective intelligence gathering and learning from each other's perspectives, participants will expand on preliminary micro-scenarios. Participants will apply systems thinking, critical analysis, as well as intuition and creative thinking in order to build more detailed, comprehensive visions that are both plausible and challenging. Each scenario will consider aspects such as data standardisation, cybersecurity, circular economy, sustainable development, and decarbonization, manufacturing models, issues related to green and digital transformation, and potential social implications of the Twin Transition goals.

In the final part of the workshop, participants will jointly identify potential implications of the scenarios for the EU and envision the role that manufacturing-as-a-service will have in each of them. They will also identify key opportunities and threats associated with each vision of the future for various stakeholders in the manufacturing sector (from business, government, academia, and society).

Workshop Agenda

Workshop participants, supported by a qualified team of moderators, will collectively explore their assumptions, share knowledge, and generate new concepts and ideas about the future of the manufacturing sector in Europe in the context of the Twin Transition. Here is the general workshop plan:

Phase 1 (1:00 - 2:00 pm)

- **Reveal:** An ice-breaker exercise designed to initiate a conversation about participants' thoughts on the future of manufacturing and uncover individual and group assumptions about potential future developments in this area.
- **Reframe:** A "confrontation" with an unexpected vision of the future, "The World Without Work"
- **Reflect:** Presentation of the MASTTT2040 project's results so far, including a discussion of key trends, drivers, and signals of change with a crucial impact on the future of the manufacturing sector in Europe.

Phase 2 (2:00 - 4:00 pm)

- **Scenario building:** Workshop participants will collaboratively develop and expand initial micro-scenarios presented by the project team using methods such as the PESTLE framework, Futures Wheel, and World Cafe. Validation of scenarios's internal consistency using an assessment of their probability and desirability.
- **Envisioning MaaS:** Drafting a desired vision of Manufacturing-as-a-Service in Europe in 2040.

Phase 3 (4:00 - 5:00 pm)

- **Scenario implications:** Analysis of opportunities and threats associated with each scenario in the context of the Twin Transition goals. Analysis of scenario implications for digitization, decarbonization, circularity, and sustainability. Examination of scenario impacts on stakeholders and various business models (such as MaaS, centralised & contract manufacturing).
- **Sense-making:** Connecting scenarios to the desired MaaS vision. Reflection on the developed scenarios in the context of the next stage of the project: strategic planning purposes at the EU-level.

Expected Results

- Minimum 3 scenarios will be developed.
- The combined realities described in the exploratory scenarios will form the high-level overview of the foreseeable strategic environment of EU manufacturing in the year 2040.
- Scenarios will also provide a framework for identification of potential future use-cases of Manufacturing as a Service.
- Each scenario will be plausible, transformative and useful for strategic planning purposes at the EU-level.
- An additional expected result is enhanced stakeholders' competencies in creating and critically analysing different visions of the future (Futures Literacy).

Practical Workshop Information

- **Date:** November 25th
- **Time:** 13:00 - 17:00
- **Location:** Polish National Centre for Research and Development Brussels office, Rue Belliard 40
- **Registration deadline:** 20 November 2024. Only registered participants will be able to attend.
- **Registration link:** <https://forms.gle/PlyJoaYbMGs9wjsA7>

Besides registering, no preparation is needed to participate in the workshop - just an open mind!

About the Workshop Organisers

This workshop is being conducted as part of the MASTT2040 project: **Manufacturing as a service for the EU's twin transition until 2040.**

MASTT2040 aims at effective implementation of a participatory, focused, strategic foresight of Manufacturing-as-a-Service (MaaS) domain to guide decision making and strategies for the EU manufacturing sector in the context of the Twin transition up to 2040. More information about the project: <https://www.mastt2040.eu/>

The project team includes the following partner institutions:

- SIRRIS-The Collective Center for the Belgian technological industry (Project Leader)
<https://www.sirris.be/en>
- COMET- Metal and Mechanical Engineering Cluster in Friuli Venezia Giulia
<https://clustercomet.it/en/>
- 4CF The Futures Literacy Company
<https://4cf.eu/>
- Steinbeis Europa Zentrum
<https://www.steinbeis-europa.de/en/home>
- FIP-Future Industry Platform
<https://przemyslprzyszlosci.gov.pl/>
- THHINKBV
<https://www.thinkbv.com/>

The workshop will be facilitated by 4CF The Futures Literacy Company and hosted by the Polish National Centre for Research and Development Brussels office.



5.2. Scenario workshop read-ahead material for participants

Drivers: forces shaping the future of manufacturing

1. **Technological advancements** – the immense pace of technological progress is one of the most important factors driving a set of changes in the manufacturing space. Increasing interconnectivity, digital transformation, the rise of smart factories, growing sophistication and accessibility of AI tools or the development of additive manufacturing - these are all changes which manufacturers have to consider and respond to in their businesses.
2. **Geopolitical shifts and economic pressures** - growing rivalry between the global powers, especially United States and China, puts a pressure on a post-Cold War model of globalisation and forces nation states to rethink their alliances. This, in turn, has a heavy impact on a business sector as various participants of the market may face the need to remodel their supply chains. What makes things even more complicated for the manufacturers, is a fact that the geopolitical shifts are accompanied by economic pressures coming from, for example, rising energy and material prices, lack of access to raw materials, or increasing labour costs.
3. **Sustainability and ethical or environmental concerns** - fear of the consequences of climate change - already experienced by societies around the world - translates into transformation of the energy sector, the growing uptake of circular models and demand for sustainable products. All of these put additional pressure on the manufacturers as they need to focus more and more on ethical or environmental factors that have not had such a meaningful impact on manufacturing up to this point.
4. **Changing consumer preferences and demands** - changes in consumer preferences and demands have always been a basic point of reference for manufacturers. Currently, thanks to technological advancement and increasing availability of new technologies, they have to deal with another set of demands coming from the consumers, manifesting in, i.e., their growing wishes for personalised products or the servitisation of economic activity.
5. **Labour market dynamics** - growing complexity of products and incredible pace of development of new technologies means that there is an increased demand for skilled, tech-savvy labour. This phenomenon does not omit the manufacturing sector. The challenge of finding skilled workers, particularly in European countries, is exacerbated by an ageing population that is shrinking the labour pool. The demographic shift is forcing manufacturers to think of new business models that assume a greater collaboration between humans and machines.
6. **Population ageing** - Population ageing means a growing proportion of older people within a population. This may be - and often is - accompanied by a decline in birth rates and increased life expectancy. Population ageing can have important implications for the manufacturing sector. It could result in a shrinking workforce, a shift in consumer demands, and a need for adaptable working environments and technologies to support, augment or replace an ageing workforce.

These drivers are interconnected and mutually reinforcing, creating a complex and evolving landscape for manufacturers as they plan for the future.

Trends in manufacturing

No	Trend	A brief overview of a trend
1	Increasing interconnectivity between companies thanks to, i.e. the IIoT	This trend encompasses a growing interconnectedness between companies, facilitated by technologies such as the Industrial Internet of Things (IIoT). Increased connectivity enables greater collaboration, data sharing, and automation across different stages of the manufacturing process, leading to improved efficiency, productivity, and innovation.
2	Digital transformation of the manufacturing sector, including increasing use of smart data and digital twins in production	This trend refers to the process of integrating digital technologies into all aspects of the manufacturing industry. It involves, i.e., the use of smart data and digital twins. The aim of the digital transformation is to improve efficiency, productivity, and flexibility in manufacturing operations.
3	Increasing speed of evolution of Artificial Intelligence (AI)	This trend is about the accelerating pace at which artificial intelligence (AI) technologies are developing and improving. It encompasses advancements in AI algorithms, hardware, and applications/tools. The trend could have various consequences for the manufacturing sector - it can lead to increased automation, improved decision-making, and enhanced product development in manufacturing. It may also transform the workforce, requiring new skills and potentially displacing jobs.
4	Growing challenges to cybersecurity of business sector	This trend refers to the increasing challenges to the cybersecurity of businesses - an off-shoot of the digital transformation. In the manufacturing sector, this trend could lead, for example, to production disruptions, data breaches, intellectual property theft, and financial losses. It also requires manufacturers to increase investment in cybersecurity measures, potentially impacting operational costs and competitiveness.
5	Growing interruptions to supply of critical minerals, materials and products	This trend refers to the increasing disruptions in the availability of essential resources required for manufacturing processes. These disruptions can result from various factors such as geopolitical tensions, trade restrictions (also sanctions), natural disasters, or logistical challenges. The trend can disrupt manufacturing in several ways. It can lead to shortages in raw materials, increased costs, and delays in production, impacting the overall efficiency and competitiveness of the sector.

6	Increasing availability of automation and the abilities of automated production systems	This trend refers to the growing accessibility and capability of automated systems in manufacturing. It encompasses the development of advanced robotics, artificial intelligence, and machine learning technologies that enable machines to perform tasks with increasing precision, speed, and adaptability. As a result, manufacturing processes may become more efficient, productive, and less reliant on human labour, especially for repetitive tasks.
7	Increasing demand for skilled, tech-savvy labour	This trend refers to the growing need for workers who possess advanced technical skills and knowledge. In manufacturing the trend is driven by the increasing complexity of manufacturing processes (as well as products), digital transformation, in particular integration of advanced technologies.
8	Rising environmental consciousness and its growing impact on manufacturing, reflected in regulations	This trend refers to the increasing public awareness and concern about environmental issues which affects business activities. As a result, manufacturers - especially in Europe - are facing stricter environmental regulations and a growing demand for sustainable products and production processes. This trend is pushing the industry towards adopting environmentally friendly practices, reducing waste and emissions, as well as investing in renewable energy sources.
9	Growing pressure to reduce supply chain vulnerabilities, due to state rivalry and various market uncertainties	This trend refers to the increasing geopolitical competition and tension between countries, especially the global powers such as the United States and China, particularly in terms of the economic and technological sway over the international order. This rivalry often leads to pressure to reduce reliance on nations that are perceived as unreliable or adversarial, especially in critical sectors like manufacturing. The trend can result in shifts in global supply chains, trade policies, and technological development as countries seek to strengthen their own industries and reduce vulnerabilities.
10	Growing cooperation between industry stakeholders (manufacturing clusters)	This trend, a result of more and more complicated processes and business environments, refers to the increasing collaboration and partnerships among various stakeholders within the industries. This cooperation can involve sharing resources, knowledge, and expertise to enhance competitiveness, innovation, and supply chain efficiency. It can also lead to the development of specialised skills and infrastructure within the cluster, fostering regional economic growth.

11	Localization of manufacturing and remanufacturing cycle, including increased tailoring of manufacturing services to local demand & regulation	This trend refers to the process of bringing manufacturing and remanufacturing activities closer to the end-users or consumers. It involves tailoring manufacturing services to meet local demands and regulatory requirements. This trend is driven by factors such as the need for shorter supply chains, reduced transportation costs, increased responsiveness to local markets, and a wish for more sustainable and resilient production processes.
12	Growing prices of energy	The trend of growing energy prices refers to the increasing cost of energy resources. This can be a result of various factors such as increased demand, limited supply, geopolitical tensions etc., many of which European countries have encountered in the last years. The growing prices of energy increase production costs, putting pressure on manufacturers' competitiveness. This trend can incentivize investments in energy efficiency and renewable energy sources, while potentially disrupting supply chains.
13	Rapid development of additive manufacturing technologies and 3D printing technologies	This trend refers to the quick advancement of technologies that create three-dimensional objects by adding material layer by layer, based on digital models. The trend could enable greater customization, shorter production times, reduced material waste, and localised production.
14	Platformisation of economic activity, including servitisation of manufacturing	This trend refers to the increasing commonness of digital platforms as a foundation for economic activities - a trend that has also influenced the manufacturing sector. It also involves a shift from traditional product-based models towards service-oriented manufacturing, where businesses offer value through integrated products and services. This can include providing maintenance, repairs, upgrades, and other value-added services alongside the physical product. The trend is driven by factors such as advancements in digital technologies, changing customer preferences, and the need for more sustainable and resilient business models.
15	Growing complexity of products	This trend refers to the increasing sophistication of manufactured products. They are becoming more complex due to factors such as technological advancements, increased customization options, and the integration of multiple functionalities. This trend can impact manufacturing processes, requiring, for example, more advanced skills, technologies, and reinvented supply chain management strategies.
16	Growing demand for personalised products	This trend refers to the increasing consumer desire for products that are tailored to their individual needs and preferences. It is driven by advancements in new technologies and a shift in consumer expectations. This trend can impact manufacturing processes, requiring more flexible and adaptable production systems capable of handling smaller batch sizes and diverse product variations.

17	China's growing capabilities in innovation and growing influx of competitively priced products from China	This trend refers to two interconnected developments - China's increasing ability to innovate and the rising quantity of affordable goods coming from the country. The former may suggest a shift in China's manufacturing focus from low-cost production to higher-value, innovative goods, threatening some of the 'traditional' manufactures of high-value goods. The latter, while beneficial for consumers seeking affordable products, can pose challenges for manufacturers in other regions due to increased cost competition.
18	Rising labour costs in Europe	This trend refers to the increasing costs associated with employing workers in European countries. It can be linked to various factors - rising wages, increased social security contributions, and the cost of complying with regulations. This trend can impact the competitiveness of European manufacturing, potentially leading to higher production costs and reduced profit margins.
19	Increase of regulations impacting business activities in Europe	This trend refers to the increasing number and complexity of regulations that businesses operating in Europe must comply with (regulations related to environmental protection, labour practices, consumer safety, data privacy etc.). The trend can create various challenges for manufacturers forcing them to rethink their models of operations, costs, risks and strategies.

Weak signals - early indicators of changes that could impact manufacturing

Security and resilience
<ul style="list-style-type: none"> ● Increasing importance of technological sovereignty. ● Increasing focus on defence production in Western economies. ● Focus on reindustrialization in policymaking. ● Nearshoring & friendshoring. ● Growing US pressure to decouple/derisk from China. ● EU's drive towards building a strong European Defense Sector. ● The rise of the economic security concept which articulates a growing need for closer cooperation between governments and business entities to more effectively defend local companies from adversarial actors.
Digitization and digital infrastructure

- Rising adoption of manufacturing platforms.
- Rise of smart factories.
- Rise of the digital twins and industrial metaverse in manufacturing,
- Increasing use of AI in decision-making processes.
- Democratisation of the use of AI in manufacturing - new solutions and applications for many actors, including SMEs.
- Quantum computing.
- Growing cybersecurity threats undermining trust in digital technologies.

Logistics and supply chains

- Increasing importance of resilience in Western economies.
- Transparent supply chains.
- Automization of logistics.
- Need for more resilient supply chains.
- Growing importance of supply and value chain digitization in manufacturing.

Business models

- Rise of collaborative production ecosystems.
- Uptake of on-demand labour models to address labour gaps.
- Increase of Data Monetization in industrial manufacturing (sell - buy - share).
- Spread of new business models based on intangible assets (creativity, culture, lifestyle etc.).
- The rise of e-commerce fulfillment centres.
- Manufacturers' growing tendency to seek value in product use (not just in their production).
- Consumers' growing interest in co-creation.

Sustainability

- Growing uptake of circular economy models in industries.
- Growing consumer demand for sustainable and ethically produced goods.
- Efforts to shorten value chains.
- Sustainable materials innovations.

Information about the Delphi study

This Delphi study, part of the MASTT 2040 Project, focused on evaluating potential disruptions to manufacturing trends. Participants were asked to assess these disruptions based on their probability of occurrence before 2040 and their potential impact on the EU's Twin Transition goals.

- **Probability** - 0% to 100%:
 - 0% - There's absolutely no chance that the disruption will become a reality before 2040
 - 100% - It's absolutely certain that the disruption will become a reality before 2040
- **Impact on the EU's ability to achieve the goals of the Twin Transition** - -3 to 3:
 - -3 this disruptive event will completely prevent the EU from achieving the goals of the Twin Transition

- 0 this disruptive event will be neutral to the EU's ability to achieve the goals of the Twin Transition
- 3 this disruptive event is a crucial enabler of the EU's ability to achieve the goals of the Twin Transition

Delphi study results

Events (potential disruptions to manufacturing trends)	Probability	Impact
Establishment of an international data exchange platform with standardized protocols, allowing seamless and secure data sharing between businesses and individuals.	56	2
Construction of the first commercially viable fusion power plant, providing a virtually limitless source of clean energy and revolutionizing the global energy landscape.	37	2
Small modular nuclear reactors become commercially viable and are commonly used in the manufacturing sector.	43	1
Smart factories become widespread, using interconnected sensors and AI to optimize energy consumption.	76	2
Collaborative production ecosystems have become commonplace in Europe.	62	1
Personalized education programs using AI to tailor learning paths to individual student needs, revolutionizing the education system as well as job training have become widespread.	72	1
The manufacturing sector in Europe has become dominated by huge conglomerates providing manufacturing services to smaller enterprises.	52	0
China becomes the global leader in technological innovation, surpassing the US and Europe in key areas like AI, robotics, and biotechnology.	72	-1
China establishes a global network of research and innovation centers, attracting top talent from around the world.	61	-1
China strategically invests in developing countries, not through direct loans, but by building manufacturing infrastructure and providing technological expertise in exchange for access to resources and markets.	79	-1
Data processing has progressed so rapidly and so far that it facilitated establishment of fully transparent supply chains and autonomization of logistics.	58	1
Development of Artificial General Intelligence (AGI), an AI with human-like cognitive abilities.	53	2
Events (potential disruptions to manufacturing trends) -cont.	Probability	Impact
AI systems become capable of independently designing, controlling and improving	63	1

manufacturing processes.		
Game-changing advancements in sustainable materials.	62	2
The use of AI leads to democratisation of manufacturing by providing easily available new solutions and applications available to a wide array of actors, including SMEs.	46	1
Cyber attacks became so widespread and destructive that it slowed down the pace of adoption of the new technologies	53	-1
The EU mandates that all products sold within its borders must have a "digital passport" detailing their environmental impact throughout their entire lifecycle.	77	2
The EU policy facilitates the establishment of a network of "agile factories" that can rapidly reconfigure their production lines to manufacture a wide range of goods, allowing the bloc to quickly respond to supply chain disruptions and changing market demands.	39	1
"Hyper-local Manufacturing Ecosystems" emerge, where companies establish micro-factories within communities, utilizing local resources and collaborating with residents to co-create and repair products.	40	1
Consumer demand for hyper-personalized products is much higher than in 2024 which puts an immense pressure on manufacturers.	64	0
A large-scale cyber attack crippling critical infrastructure in a major country, leading to widespread disruption.	61	0
Consumers become so environmentally conscious that a product's carbon footprint becomes a primary factor in their purchasing decisions.	37	1
Hyper-advanced autonomous robots are widely used in the manufacturing sector.	64	1
Despite significant advancements compared to 2024, robots still necessitate human oversight, resulting in the creation of collaborative human-machine environments within the manufacturing sector.	76	1
Friendshoring has become a dominant paradigm in the West.	52	1
Product-as-a-Service has become the dominant business model, where companies retain ownership of products and provide them to customers on a subscription basis.	62	2
Development of a breakthrough energy storage technology, enabling efficient and cost-effective storage of renewable energy.	66	2

EU manufacturing strategy

The goals of the EU manufacturing development strategy and the EU's Twin Transition, focus on four areas:

- sustainability,
- digitization,
- competitiveness and
- strategic autonomy.

Key factors fostering the sustainability of the EU Industry
<ul style="list-style-type: none"> ● Reduced operating and logistics costs ● Better product life cycle management ● Growing consumer demand for sustainability ● Government support and regulations/incentives ● Increased application of product-tracing technologies
Key factors fostering the digitization of the EU Industry
<ul style="list-style-type: none"> ● Increased application of product-tracing technologies ● Government support and regulations/incentives ● Peer-to-peer (P2P) manufacturing marketplaces ● Advanced production planning and management systems ● Reliable infrastructure ● Increasing standardisation
Key factors fostering the competitiveness of the EU Industry
<ul style="list-style-type: none"> ● Greater flexibility ● Reduced operating and logistics costs ● Increasing smart specialisation (geographically) ● Increased application of blockchain technology ● Government support and regulations/incentives ● Peer-to-peer (P2P) manufacturing marketplaces
Key factors fostering the strategic autonomy of the EU Industry
<ul style="list-style-type: none"> ● Greater flexibility ● Increasing smart specialisation (geographically) ● Increased application of product-tracing technologies ● Government support and regulations/incentives ● Increasing standardisation ● Reliable infrastructure

