Disruptive Events REPORT

Introduction

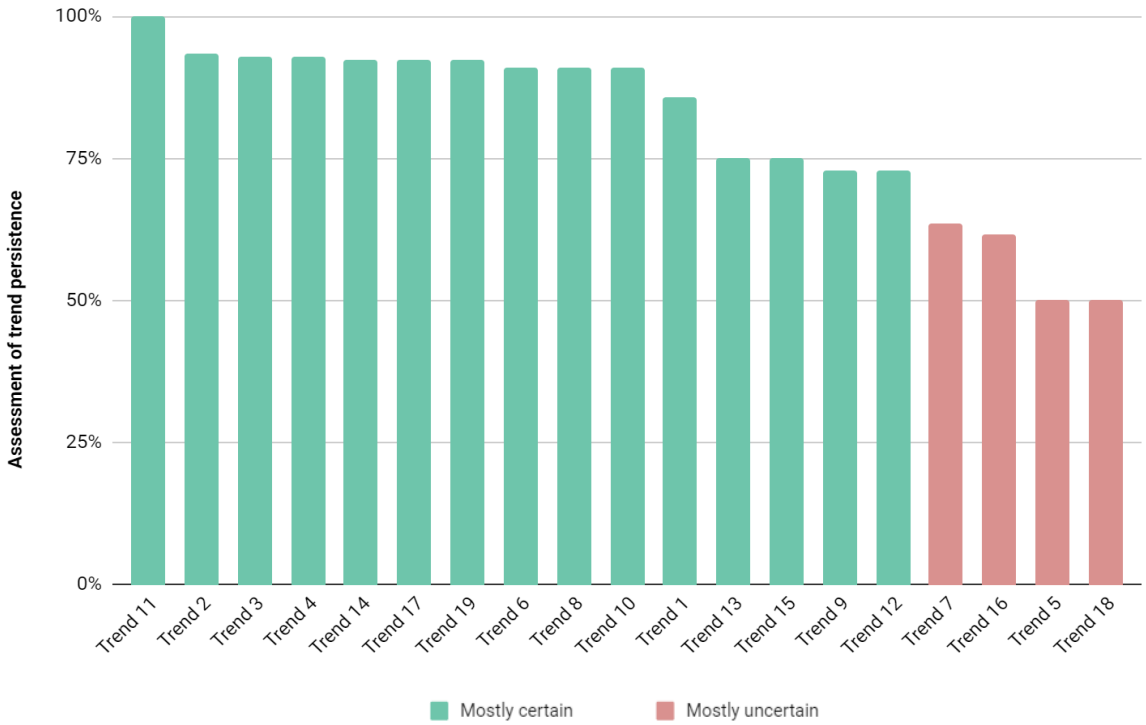
This document offers a comprehensive analysis of "Disruptive Futures in Manufacturing," an asynchronous workshop conducted as part of the MASTT2040 Project using the 4CF Sprawlr tool. The workshop focused on gathering expert opinions on the expected continuation or potential uncertainty of 19 key trends previously identified within the MASTT2040 project. The goal of the task was also to explore potential disruptions to trends that may have an impact on the future of manufacturing. Trends and their disruptions will constitute building blocks of the scenarios of the future of manufacturing that will be created as a part of the MASTT 2040 Project.

Results

Measuring trend uncertainty

The "Disruptive Futures in Manufacturing" study explored potential disruptions and trends that could shape the future of manufacturing. Respondents were asked to rate 19 trends by indicating whether they believed a given trend would continue or whether its future was uncertain.

Figure 1. Evaluating trend uncertainty levels.



Trend 11	Localization of manufacturing and remanufacturing cycle, including increased tailoring of manufacturing services to local demand & regulation	**Trend 1**	Increasing interconnectivity between companies thanks to, i.e. the IIoT
Trend 2	Digital transformation of the manufacturing sector, including increasing use of smart data and digital twins in production	**Trend 13**	Rapid development of additive manufacturing technologies and 3D printing technologies
Trend 3	Increasing speed of evolution of Artificial Intelligence (AI)	**Trend 15**	Growing complexity of products
Trend 4	Growing challenges to cybersecurity of business sector	**Trend 9**	Growing pressure to reduce supply chain vulnerabilities, due to state rivalry and various market uncertainties
Trend 14	Platformization of economic activity, including servitization of manufacturing	**Trend 12**	Growing prices of energy
Trend 17	China's growing capabilities in innovation and growing influx of competitively priced products from China	**Trend 7**	Increasing demand for skilled, tech-savvy labor
Trend 19	Increase of regulations impacting business activities in Europe	**Trend 16**	Growing demand for personalized products
Trend 6	Increasing availability of automation and the abilities of automated production systems	**Trend 5**	Growing interruptions to supply of critical minerals, materials and products
Trend 8	Rising environmental consciousness and its growing impact on manufacturing, reflected in regulations	**Trend 18**	Rising labor costs in Europe
Trend 10	Growing cooperation between industry stakeholders (manufacturing clusters)		

Analysis of the results reveals a general consensus among the experts on the future of most trends. For 15 trends (labelled "Most Certain" in Figure 1), a majority of respondents voted for the trend to continue. However, there were disagreements for four trends (labelled "Mostly Uncertain" in Figure 1), where ⅓ or more of the votes were cast against the continuation of the trend.

Strong agreement was observed for the following trends that respondents believe will continue to shape the future of manufacturing:

- **Trend 11:** Localization of manufacturing and remanufacturing cycle, including increased tailoring of manufacturing services to local demand & regulation;
- **Trend 2:** Digital transformation of the manufacturing sector, including increasing use of smart data and digital twins in production;
- **Trend 3:** Increasing speed of evolution of Artificial Intelligence (AI);
- **Trend 4:** Growing challenges to cybersecurity of business sector;
- **Trend 14:** Platformization of economic activity, including servitization of manufacturing;
- **Trend 17:** China's growing capabilities in innovation and growing influx of competitively priced products from China;
- **Trend 19:** Increase of regulations impacting business activities in Europe;
- **Trend 6:** Increasing availability of automation and the abilities of automated production systems;
- **Trend 8:** Rising environmental consciousness and its growing impact on manufacturing, reflected in regulations;
- **Trend 10:** Growing cooperation between industry stakeholders (manufacturing clusters).

For these trends, "pro" votes (trend will persist) accounted for over 90% of the responses, with a high level of expert participation.

Conversely, the trends associated with the greatest uncertainty were:

- **Trend 5:** Growing interruptions to supply of critical minerals, materials and products;
- **Trend 18:** Rising labour costs in Europe;
- **Trend 7:** Increasing demand for skilled, tech-savvy labour;
- **Trend 16:** Growing demand for personalised products.

For these trends, "con" votes (expressing uncertainty about the future of the trend) exceeded ⅓ of the responses, indicating a lack of consensus and highlighting the difficulty of predicting their trajectory. This divergence in expert opinion underscores the dynamic and unpredictable nature of these trends and their potential to disrupt the manufacturing landscape.

Exploring potential disruptions

Trend 1 Increasing interconnectivity between companies thanks to, i.e. the IIoT

Table 1. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
86%	14%	mostly certain

Experts were largely in agreement about the future direction of Trend 1, which is the increasing interconnectivity between companies thanks to, i.e. the IIoT. The majority of votes cast indicate that this trend is likely to continue in the future.

According to the experts, several factors **could accelerate** the development of interconnectivity in the industry. They pointed to the growing need for data exchange for more efficient planning and co-design of new products. Experts also highlighted the key role of sharing data across silos to achieve benefits in terms of supply chain sustainability, service delivery and increasing the resilience of production systems.

Trend 2 Digital transformation of the manufacturing sector, including increasing use of smart data and digital twins in production

Table 2. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
93%	7%	mostly certain

Experts agreed on the future of trend 2, which concerns the digital transformation of manufacturing, including the increasing use of smart data and digital twins. Most of them speculate that this trend will continue in the future.

According to the experts, several factors **could accelerate** the digital transformation of the industry. First, the rapid pace of technological development, both in the area of digital twins and other digital tools, could have a significant impact on the manufacturing sector. Second, companies that have already accumulated large amounts of data are now looking for ways to harness its potential. Third, access to data and data sharing (both

within and between companies) are essential to achieving breakthrough solutions in manufacturing. The use of smart data through analytics and artificial intelligence could be the key to achieving these benefits.

Trend 3 Increasing speed of evolution of Artificial Intelligence (AI)

Table 3. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
93%	7%	mostly certain

The experts' opinions on the future of trend 3, the Increasing speed of evolution of Artificial Intelligence (AI), were convergent. Most of them believe that this trend will be sustained in the future.

According to the experts, several factors **could accelerate** the development of AI. They pointed to the rapid progress in the subsequent stages of AI development (Generative AI, Agentic AI, Artificial General Intelligence, and Superintelligence), whose potential applications in manufacturing are still in their early stages. The development of AI presents both huge opportunities and risks, and there is uncertainty about when the next stages will become available.

Experts also emphasised that AI can help automate repetitive tasks and improve communication between different parties. Currently, it is difficult to maintain ongoing communication and keep track of all status updates due to lack of time and resources. Generative AI can help summarise and manage this information.

Trend 4 Growing challenges to cybersecurity of business sector

Table 4. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
93%	7%	mostly certain

Experts agreed on the future of Trend 4, which relates to the growing challenges of cybersecurity in the business sector. Most believe that this trend will continue in the future and that cyber threats will continue to escalate.

According to the experts, several factors could further **exacerbate** the cybersecurity situation. They point to the growing number of conflicts between countries or specific companies in which cyber-attacks become a tool of warfare.

Experts also stress that cybersecurity is the Achilles' heel of digitalization and artificial intelligence. What brings new opportunities also brings enormous risks. Cybersecurity will have to keep pace with rapid technological development and the need to share data.

Trend 5 Growing interruptions to supply of critical minerals, materials and products

Table 5. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
50%	50%	mostly uncertain

Experts were divided on the future of Trend 5, which relates to growing interruptions in the supply of critical minerals, materials and products. Half of the respondents expressed uncertainty about the future of this trend, suggesting a possible change in direction.

Experts point to several factors that could contribute to a weakening of this trend. They note that in a linear economic model, the demand for new raw materials will increase, while in the case of the development of a circular economy (with an emphasis on longer use of products and materials and their reuse at the end of their life cycle), this trend may slow down. Experts emphasise the role of regulations, new technologies and business models as drivers for reducing dependence on new raw materials.

Trend 6 Increasing availability of automation and the abilities of automated production systems

Table 6. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
91%	9%	mostly certain

Experts were in agreement about the future of trend 6, the increase in the availability of automation and the capabilities of automated production systems. Most believe that this trend will persist and automation will continue to play an increasingly important role in industry.

According to the experts, several factors could further accelerate the development of automation. First and foremost, they point to technological advances, particularly in artificial intelligence (AI) and robotics, that are being applied to production systems.

Experts point out that industrial automation has already reached a very high level. Integration with robotic systems and computer vision will make it possible to replace some of the remaining manual activities. The further development of automation will be stimulated not only by flexible automated production systems, but also by the digitization and automation of knowledge processes, driven by AI.

Trend 7 Increasing demand for skilled, tech-savvy labour

Table 7. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
64%	36%	mostly uncertain

Experts were divided on the future of Trend 7, the increasing demand for skilled, tech-savvy labour. More than one-third of respondents expressed uncertainty about the future of this trend, suggesting a possible change in direction.

Experts point to factors that could accelerate this trend. They believe that as automation and artificial intelligence (AI) take over simple, routine tasks, workers will need new skills to operate and collaborate with these systems. This will increase the demand for professionals with knowledge and skills in digital technologies, AI, and automation.

Trend 8 Rising environmental consciousness and its growing impact on manufacturing, reflected in regulations

Table 8. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
91%	9%	mostly certain

Experts agreed on the future of Trend 8, rising environmental consciousness and its growing impact on manufacturing, reflected in regulations. Most believe this trend will continue and that sustainability issues will play an increasingly important role in industry.

According to the experts, several factors could further strengthen this trend. Among other things, they point out that the transition to more environmentally sustainable manufacturing will be driven by new regulations. The introduction of the Digital Product Passport, which is currently being developed, will increase consumer awareness of the environmental impact of products.

Trend 9 Growing pressure to reduce supply chain vulnerabilities, due to state rivalry and various market uncertainties

Table 9. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
73%	27%	mostly certain

The experts expressed a convergence of views on the future of Trend 9, which relates to the Growing pressure to reduce supply chain vulnerabilities, due to state rivalry and various market uncertainties. Most believe that this trend will continue into the future and that supply chain disruption issues will remain relevant.

However, they also see factors that could slow this trend. They point out that this is a hot topic today and that by 2040, solutions should be in place to reduce supply chain vulnerability to disruption. These solutions include information sharing along the supply chain, easier access to alternative suppliers and materials, and the creation of closed-loop systems that enable local sourcing of materials.

Trend 10 Growing cooperation between industry stakeholders (manufacturing clusters)

Table 10. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
91%	9%	mostly certain

The experts' opinions on the future of Trend 10, the growing cooperation between industry stakeholders (manufacturing clusters), were convergent. Most believe that this trend will continue and that industry collaboration will continue to develop.

According to the experts, there are several factors that could further strengthen this trend. They emphasise the need to share innovations and strategies for increasing resilience among different entities in the industry. Cooperation at different levels and within entire ecosystems is essential to maintain the EU's competitiveness in the global market. Cooperation between suppliers and customers will also be essential to improve flexibility in production.

At the same time, experts note that the future shape of ecosystems and clusters and how they will cooperate is still unknown. Will they be dominated by large companies or will they take a more collaborative approach?

Trend 11 Localization of manufacturing and remanufacturing cycle, including increased tailoring of manufacturing services to local demand & regulation

Table 11. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
100%	0%	mostly certain

Experts agreed on the future of Trend 11, the localization of manufacturing and remanufacturing cycle, including increased tailoring of manufacturing services to local demand & regulation. Most believe this trend will continue in the future.

According to the experts, several factors could accelerate the development of this trend. Among other things, they point out that new servitization models will be essential to increase the sustainability of production. This, in turn, will bring machine producers closer to their customers.

Trend 12 Growing prices of energy

Table 12. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
73%	27%	mostly certain

The experts agree on the future of Trend 12, which relates to rising energy prices. Most believe that this trend will continue and that energy prices will continue to rise.

According to the experts, several factors could further accelerate the rise in energy prices. They point out that this is a real problem both now and in the coming years, as current technological trends are quite energy-intensive. The rise in energy prices is influenced by a complex interplay of different factors. We can observe an increase in energy demand, the introduction of carbon pricing and the costs of transitioning to renewable energy sources, as well as challenges related to infrastructure and the energy grid.

However, experts also see factors that could slow the rise in energy prices. Improved energy efficiency and the declining cost and increasing scale of renewable energy sources could contribute to lower energy prices. They point to the rapid decline in the price of renewable energy. In addition, artificial intelligence (AI) is accelerating scientific advances in nuclear energy and green hydrogen, which could outweigh the current trend of rising energy prices in the future.

Trend 13 Rapid development of additive manufacturing technologies and 3D printing technologies

Table 13. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
75%	25%	mostly certain

The experts expressed a convergence of opinions on the future of trend 13, which relates to the rapid development of additive manufacturing technologies and 3D printing technologies. Most of them believe that this trend will continue and that these technologies will continue to develop dynamically.

According to the experts, one of the factors accelerating the development of additive manufacturing is the growing demand for small-scale, customised production, which requires this type of technology. 3D printing enables the rapid and flexible production of prototypes and end products that are tailored to customers' individual needs.

Trend 14 Platformization of economic activity, including servitization of manufacturing

Table 14. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
92%	8%	mostly certain

The experts expressed convergent opinions on the future of trend 14, which concerns the platformization of economic activity, including servitization of manufacturing. Most of them believe that this trend will continue and that platforms and servitization will play an increasingly important role in industry.

According to the experts, several factors could accelerate the development of this trend. Among other things, they point out that servitization is the key to coping with rapid market changes. Companies can no longer afford to buy and maintain machines for decades as they did in the past. Servitization allows them to flexibly use the latest technologies and adapt to the changing needs of customers.

Trend 15 Growing complexity of products

Table 15. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
75%	25%	mostly certain

Experts expressed convergent opinions about the future of trend 15, concerning the growing complexity of products. Most of them believe that this trend will persist.

According to experts, one factor accelerating this trend is the need to satisfy the needs of all consumers, which will impact manufacturing processes. Companies will have to adapt to the growing expectations of customers and offer increasingly diverse and technologically advanced products.

Trend 16 Growing demand for personalised products

Table 16. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
62%	38%	mostly uncertain

Experts are divided on the future of trend 16, the growing demand for personalised products. More than a third of respondents expressed doubts about the future of this trend, suggesting a possible change in direction.

Experts point to factors that could contribute to a weakening of this trend. They note that the trend toward product personalization has been around for a long time and that many products are already hyper-personalised. In the future, personalization may shift from the physical products themselves to the services and applications associated with them. The same product could then support different applications and meet the individual needs of users.

Trend 17 China's growing capabilities in innovation and growing influx of competitively priced products from China

Table 17. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
92%	8%	mostly certain

Experts agreed on the future of Trend 17, which relates to China's growing capabilities in innovation and growing influx of competitively priced products from China. Most believe that this trend will continue and that China will continue to strengthen its position as an innovation leader.

According to the experts, several factors could accelerate this trend. They point to the considerable financial capacity of the Chinese government, which can invest heavily in selected sectors of the economy. In Europe, funding is less concentrated and available on a smaller scale.

Experts also highlight China's long-term innovation and support strategy, which has allowed the country to move from being an imitator to an innovative leader. China currently offers high quality and innovative products at competitive prices. Europe needs to accelerate the pace of innovation to keep pace with China.

Trend 18 Rising labour costs in Europe

Table 18. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
50%	50%	mostly uncertain

Expert opinion is divided on the future of trend 18, which relates to rising labor costs in Europe. Half of the respondents expressed uncertainty about the further development of this trend, suggesting the possibility of a change in its direction.

The experts point to a number of factors that could influence both the acceleration and the deceleration of labor cost growth. However, they do not agree on which of these factors will have a significant impact in the future. Differences in the assessment of each event make it impossible to say definitively whether labor costs in Europe will rise or fall.

Trend 19 Increase of regulations impacting business activities in Europe

Table 19. Assessment of trend persistence.

Positive ratings	Negative ratings	Overall rating
92%	8%	mostly certain

The experts expressed a convergence of views on the future of trend 19, which relates to the increase of regulations impacting business activities in Europe. Most believe that this trend will continue and that the number of regulations will continue to grow.

According to the experts, regulations on sustainability impact and data governance could contribute to accelerating this trend. Their aim is to maintain the high quality of production in Europe and limit external competition. Experts expect more regulations in these areas to emerge in the future, impacting the way companies operate in Europe.

Conclusions

During the "Disruptive Futures in Manufacturing" workshop the manufacturing stakeholders elaborated on the level of uncertainty of the trends. They largely agreed on the continuation of trends such as localization, digital transformation, AI advancement, cybersecurity challenges, platformization, and the impact of China's innovation. Uncertainties between the manufacturing stakeholders arose mainly with regard to supply chain interruptions, labour costs, skilled labour demand and personalised product demand.

The workshop discussions also shed light on potential disruptions to the identified trends. For example, experts highlighted factors such as the interplay between circular economy models and raw material demand, the evolving skill requirements driven by automation and AI, and the impact of geopolitical conflicts and technological advancements on supply chain vulnerabilities. Their suggestions will be a basis of further analysis with the goal to clearly define potential disruptive events that may sway the future of manufacturing. Then, the disruptive events will be further analysed through the prism of their probability and potential impact on the Twin Transition during the Delphi study.