MASTT2040

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

D2.2 Manufacturing as a Service and digital technologies in manufacturing: strategic foresight manual

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1. Executive summary

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.

The strategic foresight manual explains the strategic foresight methodology designed to support the objectives of the MASTT2040 project and to increase the futures literacy of its stakeholders. The document provides a realistic perspective on strategic foresight as a tool to explore plausible futures, identify emerging trends, and enable informed decisions. The methodology recognizes the non-linear, dynamic nature of the future, emphasizing the influence of present actions on multiple potential outcomes.

The document provides an overview of the methods, including brainstorming workshops, the Delphi Method, horizon scanning, (G)PESTLEI, Prob-Imp analysis, roadmapping, scenario analysis, SWOT, and trend analysis. It also details the four main phases of the strategic foresight process and how they can be implemented. Each method's relevance, implementation process, and application in the main phases of strategic foresight **in** MASTT2040 is highlighted.

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 "Manufacturing as a Service and digital technologies in manufacturing: strategic foresight manual" is a deliverable linked to WP2 Envisioning & Reframing and it provides guidance on applying strategic foresight methodologies within the context of MaaS and the twin transition. It serves as a knowledge foundation, equipping project partners and stakeholders with a common understanding of foresight concepts, methods, and best practices. The manual directly supports the identification and analysis of key trends, facilitating the development of plausible future scenarios for MaaS. Furthermore, it aids in stakeholder engagement by fostering a shared understanding and enhancing communication among participants. It is designed to boost the futures literacy of project stakeholders. By using the tools and methods within, they'll gain the skills and confidence to analyze trends, anticipate challenges, and explore potential opportunities. This increased understanding of the future will enable them to develop their own long-term plans and strategies, adapting the methodology to their specific needs and goals, whether within the manufacturing landscape or beyond. Ultimately, this manual equips individuals and the project as a whole to make informed decisions and navigate the complexities of the future with greater clarity and foresight.

3. Strategic foresight theory

3.1. Strategic foresight explained

Strategic foresight is a crucial discipline that empowers us to navigate the complexities of the future. It challenges the common assumption that the future is merely an extension of the past, recognising instead that the future is shaped by dynamic forces, unexpected disruptions, and a multitude of possibilities.

At its core, strategic foresight rests on three fundamental premises:

- **The future is not predictable.** We cannot simply extrapolate current trends to understand what lies ahead. Instead, we must consider a range of plausible futures, acknowledging the inherent uncertainty and ambiguity of the world around us.
- **The future is not predetermined.** There is an infinite number of potential futures, and our choices in the present can influence which of these possibilities becomes reality.
- **To some extent, we can influence the future through our present-day actions.** While we cannot control the future, we can shape its trajectory by making informed choices and taking deliberate action.

Strategic foresight emerged from the field of Futures Studies, which has been developing frameworks and methodologies for exploring the future since the 1940s. Its practical application lies in helping decision-makers at all levels – national, regional, sectoral, and organisational – to anticipate future challenges and opportunities and make more informed choices in the present.

In essence, strategic foresight can be understood as a human and organisational competence that enhances our ability to understand the forces shaping the future. By considering a range of possible futures, we can identify emerging trends, potential disruptions, and critical uncertainties. This knowledge allows us to make more informed decisions, develop more robust strategies, and foster a culture of innovation and learning.

3.2. A realistic perspective on strategic foresight

The value of strategic foresight lies in its ability to provide anticipatory intelligence, enabling us to identify "weak signals" of change and respond proactively to emerging opportunities and threats. It supports timely and efficient decision-making by informing the development and adaptation of organisational visions, strategies, and priorities. Furthermore, it catalyses organisational innovation by fostering a forward-looking culture that embraces new knowledge and novel solutions.

Strategic foresight also cultivates a continuous learning attitude by encouraging organisations to constantly adapt and refine their strategic choices. It enhances our competencies by challenging us to break free from habitual patterns of thinking and acting. And it strengthens organisational leadership by providing leaders with the insights they need to make informed decisions that consider the long-term implications.

However, it is crucial to understand what strategic foresight cannot do. It is not a substitute for strategic planning and decision-making, but rather a tool to enhance these processes. It cannot single-handedly modernise a research and innovation system, nor can it guarantee consensus or automatically lead to action.

Ultimately, strategic foresight is an invaluable asset for any actor, public or private, who seeks to navigate the complexities of the future, develop robust strategies, foster a holistic understanding of their environment, and stay ahead of the curve in a rapidly changing world.

4. Overview of selected strategic foresight methods

4.1. Brainstorming workshop

4.1.1 Short overview

Brainstorming is a valuable tool for generating creative ideas and fostering collaboration. By encouraging a free and open exchange of thoughts without judgment, brainstorming unlocks the collective imagination of a group. This process, often used in the early stages of futures workshops and various other settings, involves encouraging participants to share ideas freely, no matter how unconventional or seemingly impractical. The core principle behind brainstorming is that quantity breeds quality; the more ideas generated, the greater the chance of discovering innovative solutions.

In a structured setting, brainstorming can be particularly effective in guiding participants away from conflict and towards consensus. It allows individuals to build upon each other's ideas, fostering a sense of shared ownership and commitment to the outcome. The main advantage of brainstorming lies in its ability to generate fresh perspectives and novel approaches to problem-solving. The open and accepting atmosphere encourages creative thinking, where even seemingly incomplete or "wild" ideas can spark inspiration and lead to breakthrough solutions.

4.1.2 Mode of implementation

Brainstorming is a readily accessible and versatile technique that can be employed in virtually any setting. With minimal resources required – essentially a skilled facilitator and a means of capturing and presenting ideas – brainstorming can be easily implemented.

To maximise the effectiveness of a brainstorming session, various techniques can be employed to stimulate idea generation and enhance productivity. These techniques include role-playing, mind mapping, storyboarding, and card clustering, each offering a unique approach to exploring and organising ideas.

Optimally, brainstorming sessions involve small groups of 7 to 12 participants to ensure active engagement and facilitate a focused discussion. Larger groups can be divided into smaller teams to maintain the dynamism and effectiveness of the brainstorming process.

4.1.3 Relevance of the method

- Brainstorming is a powerful tool for tapping into the collective intelligence of expert committees and consultation groups. It excels at generating a wealth of ideas and perspectives, making it particularly valuable in situations where a comprehensive understanding of a topic is needed before embarking on problem-solving, decision-making, or planning. This technique also proves useful in scenario analysis, where exploring a wide range of possibilities is essential.

- Beyond its capacity for idea generation, brainstorming serves as an effective icebreaker, fostering a collaborative and open-minded atmosphere within a group. It encourages participants to shed inhibitions and share unconventional ideas, paving the way for a more creative and productive working session. While the results of brainstorming may not always offer immediate or specific solutions, they serve as a crucial foundation for a more comprehensive and targeted process.

4.1.4 Further reading

http://foresight-platform.eu/community/forlearn/how-to-do-foresight/methods/creative-methods/brainstorming/

4.2 Delphi Method

4.2.1 Short overview

The Delphi method is a structured group interaction process, in which individuals are requested to give numerical judgments about future developments in science, technology, society, policy etc.

Main objectives of the surveys of the Delphi method are to obtain consensual expert opinions, gather well-informed assessments, anticipate uncertain events, generate ideas and provide additional information about developments under study. Delphi also serves a communication and awareness raising function among the participants. This function is supported by the anonymity of the process, which ensures that experts can express their opinion (or evaluate the opinions of others) without perceived social pressure from survey participants.

The results of the Delphi method can be used to provide guidelines for policy, to help determine priorities, to advocate for new research or business initiatives or to communicate, raise awareness and inform the general public.

4.2.2 Mode of implementation

The Delphi method is usually conducted in the form of a structured questionnaire, with experts providing assessments of “Delphi theses”. The survey can be conducted in a turn-based or a continuous (real-time) form. The preparation of the Delphi survey can be relatively time consuming, but it largely depends on the used Delphi platform, the variant of the survey and other factors. Usually Delphi surveys take between 2 weeks and a couple of weeks to conduct. The Delphi method is characterized by its focused approach, involving a small group of 10-20 key experts who provide their insights on a limited set of 10-20 Delphi theses.

This interactive process can be conducted in two primary ways:

- Turn-based: Experts respond to the questionnaire in rounds, with each round building upon the feedback from the previous one. This allows for reflection and refinement of opinions as the process unfolds.
- Continuous (real-time): Experts engage in a dynamic exchange of ideas and feedback in a real-time online environment, fostering a more immediate and interactive discussion, while also decreasing the time needed to conduct the survey.

While the Delphi method offers valuable insights, it's important to acknowledge that preparing a well-structured questionnaire and facilitating the iterative process of gathering and synthesising expert opinions can be time-consuming and requires experience.

4.2.3 Relevance of the method

The Delphi method offers a robust framework for integrating expert knowledge into strategic processes. It excels at fostering communication and facilitating the exchange of perspectives on complex topics. Notably, it allows for the capture and analysis of tacit knowledge – the intuitive insights and experience-based wisdom of experts – which proves invaluable for long-term assessments where traditional forecasting methods based on extrapolations fall short. This makes the Delphi method particularly well-suited for exploring areas where data is scarce - as is the case in most complex topics related to the future.

The method's strength lies in its ability to:

- Identify and prioritise policy goals: By harnessing the collective intelligence of experts, the Delphi method can help determine the most critical objectives and guide strategic decision-making.
- Provide diagnostic assessments in uncertain environments: When faced with ambiguity and incomplete information, the method offers a structured approach to gathering expert opinions and navigating complexity.

However, the Delphi method also presents certain challenges:

- Expert selection: The quality of the study hinges on the selection of knowledgeable and diverse experts, as the results reflect the perspectives of the chosen group.
- Thesis formulation: Clearly defined and well-articulated thesis statements are crucial, as poorly framed questions can lead to ambiguous or irrelevant information.
- Time commitment: The iterative nature of the Delphi method can be time-consuming for both organisers and participants.

Despite these challenges, the Delphi method remains a valuable tool for gathering expert opinions, fostering informed decision-making, and navigating the complexities of the future.

A Delphi survey yields two primary types of output:

- Quantitative data: This comprises the ratings and rankings provided by experts on the Delphi theses. These assessments, derived from a collective intelligence process and free from authority bias due to anonymity, offer valuable insights into the relative importance and plausibility of different scenarios.
- Qualitative data: When respondents are given the opportunity to elaborate on their ratings and provide justifications, a rich layer of qualitative data emerges. This data sheds light on the reasoning behind the quantitative assessments and offers valuable context and insights for further analysis. Real-time Delphi surveys, in particular, facilitate this type of in-depth exploration.

In conclusion, the Delphi method provides a powerful mechanism for harnessing expert knowledge, navigating uncertainty, and informing strategic decision-making. By combining quantitative and qualitative insights, it offers a comprehensive understanding of complex issues and empowers organizations to make more informed choices about the future.

4.2.4 Further reading

Cuhls, K. (2005): Delphi surveys, Teaching material for UNIDO Foresight Seminars. http://www.foresight.pl/assets/downloads/publications/UNIDO-Technology-Foresight-Manual_vol2.pdf

Gordon, T. J. (2009). The real-time Delphi method. Futures research methodology https://millennium-project.org/wp-content/uploads/2022/01/05-Real-Time-Delphi.pdf

4.3 Horizon scanning/Weak signals

4.3.1 Short overview

Horizon scanning is a systematic process of exploring the future landscape to identify early signs of potentially significant developments. It involves looking beyond the obvious, seeking out weak signals, emerging trends,

unexpected disruptions ("wild cards"), and other factors that may challenge existing assumptions and shape the future. This exploration can be broad and open-ended, or it can be focused on specific areas of interest, depending on the objectives of the project or task at hand.

Essentially, horizon scanning seeks to understand the dynamics of change by examining what remains constant, what is susceptible to change, and what is in a state of continuous evolution within a defined timeframe. This process often involves applying a set of criteria to filter and prioritise the identified signals. The time horizon for analysis can vary, encompassing short-term, medium-term, or long-term perspectives.

Horizon scanning provides a structured approach to gathering intelligence about the future. It focuses on identifying signals that meet specific criteria:

- Credibility: Signals should be based on credible observations of current or imminent changes, whether sudden or gradual.
- Shareability and analysability: Signals should be easily communicated, elaborated upon, and assessed by stakeholders.
- Relevance to emerging issues: Signals should point towards potentially significant developments that may have been overlooked or underestimated.

By systematically identifying and analysing these signals, horizon scanning empowers organisations to anticipate change, adapt proactively, and make more informed decisions about the future.

4.3.2 Mode of implementation

Horizon scanning is a comprehensive process of identifying emerging issues by systematically exploring a wide range of information sources. This involves two primary approaches:

- Analysing diverse data from various "signal" sources: This approach casts a wide net, examining a variety of sources such as news articles, scientific publications, social media trends, and expert opinions to identify weak signals and emerging trends.
- Identifying core documents that highlight potential issues: This approach focuses on pinpointing key documents, reports, or studies that provide in-depth analysis of specific issues and their potential implications.

To effectively scan the horizon, a variety of tools and techniques are employed, including manual scanning, wiki platforms, expert surveys, conferences and workshops, social media monitoring, text mining. By combining these approaches and leveraging a diverse toolkit, horizon scanning provides a robust framework for anticipating change and staying ahead of the curve.

4.3.3 Relevance of the method

Integrating horizon scanning into the broader foresight process empowers policymakers to make more informed and proactive decisions. By systematically exploring the future landscape, horizon scanning helps

identify critical needs and gaps in existing policies, enabling more effective risk management and preparedness for potential opportunities and threats.

This continuous monitoring of the horizon provides timely insights into emerging trends and potential disruptions, allowing policymakers to adapt strategies and strengthen the resilience of policies in the face of change.

Furthermore, horizon scanning plays a crucial role in identifying weak signals, early warnings, and potential "wild cards" – those low-probability but high-impact events that could significantly disrupt the status quo. This early detection provides valuable time for policymakers to develop strategies and mitigate potential risks before they escalate into crises.

In essence, horizon scanning shifts policymaking from a reactive to a proactive stance. By identifying potential problems at an early stage, policymakers can take preemptive action, address challenges before they become critical, and seize opportunities as they emerge. This proactive approach enhances the agility and effectiveness of policymaking in a rapidly changing world.

4.3.4 Further reading

European Commission (2015). Models of horizon scanning: How to integrate horizon scanning into European research and innovation policies.

https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccv/2015/Models-of-Horizon-Scanning.pdf

Cuhls K., Giessen van der A., Toivanen H., Models of Horizon Scanning. How to integrate Horizon Scanning into European Research and Innovation Policies, 2015.

UN Global Pulse, Horizon Scan User Manual: A step-by-step guide, Anticipation Capability, 2022.

Amanatidou E., Butter M., Carabias V., Könnölä T., Leis M., Saritas O., Schaper-Rinkel P., Rij van V., On concepts and methods in horizon scanning: Lessons from initiating policy dialogues on emerging issues, Science and Public Policy, Volume 39, Issue 2, March 2012, pp. 208–221, https://doi.org/10.1093/scipol/scs017.

4.4 (G)PESTLEI

4.4.1 Short overview

(G)PESTLEI analysis is a variant of the strategic foresight method (PESTLE analysis) used to examine the macro-environmental factors that can impact an organisation, sector, or region. It stands for (Geo)political, Economic, Social, Technological, Legal, Environmental, and Industrial. By systematically analysing these factors, decision-makers can better understand the current landscape, anticipate future trends, and develop more robust and resilient strategies.

4.4.2 Mode of implementation

- Identify the relevant factors: Begin by brainstorming a comprehensive list of potential factors within each (G)PESTLEI category that could affect the area being analysed.
- Gather information: Collect data and information related to each factor, drawing on a variety of sources, such as industry reports, government publications, news articles, academic research, and expert opinions.
- Analyse the impact: Assess the potential impact of each factor, considering both the likelihood and magnitude of its effects. This may involve qualitative assessments, quantitative analysis, or a combination of both.
- Develop strategic responses: Based on the analysis, identify potential opportunities to leverage and threats to mitigate. Develop strategies and action plans to proactively address these factors and enhance resilience.

4.4.3 Relevance of the method

(G)PESTLEI provides a holistic framework for analysing the external environment, ensuring that key factors are not overlooked. It helps identify potential opportunities and threats, informing the development of more robust and future-proof strategies. By anticipating potential challenges, organisations can proactively manage risks and enhance their resilience. Understanding external factors can spark innovation by identifying new market opportunities or technological advancements. (G)PESTLEI can inform policy decisions by providing insights into the broader context and potential impacts of policy changes.

4.4.4 Further reading

https://pestleanalysis.com/what-is-pestle-analysis/

4.5 Prob-Imp analysis

4.5.1 Short overview

Probability-impact analysis is a tool used to assess the likelihood and potential impact of different risks or opportunities. It is a valuable tool for decision-making, as it allows to prioritise risks and opportunities based on their potential impact and the likelihood of them occurring.

4.5.2 Mode of implementation

To effectively perform Probability-impact analysis one should start identifying the risks and opportunities that are relevant to a given organisation, project or decision. The next step is to assess the likelihood of each risk or opportunity occurring and its potential impact (on the topic of interest). This is followed by a calculation of the probability-impact score for each risk or opportunity. The final step is to prioritise the risks

and opportunities based on their probability-impact scores to develop strategies to mitigate the risks and capitalise on the opportunities.

4.5.3 Relevance of the method

Probability-impact analysis is a versatile tool that can be used in a variety of contexts, including:

- Project management.
- Risk management.
- Strategic planning.
- Decision-making.

It is a valuable tool for identifying and prioritising risks and opportunities, and for developing strategies to mitigate risks and capitalise on opportunities.

4.5.4 Further reading

https://css.ethz.ch/content/dam/ethz/special-interest/gess/cis/center-for-securities-studies/pdfs/RR-Reports-2021-StrategicForesight.pdf

https://www.rosemet.com/probability-and-impact-matrix/

4.6 Roadmapping

4.6.1 Short overview

Roadmapping has evolved into a versatile and widely adopted management technique for driving innovation and shaping strategy across various levels, from individual firms to entire sectors and nations. While roadmaps can take many forms, their essence lies in providing a structured and visual representation of a strategic journey.

Imagine a multi-layered chart that unfolds over time, offering a comprehensive view of the path ahead. This is the essence of a roadmap. It serves as a unifying framework, aligning different functions and perspectives within an organization to answer three fundamental questions:

- Where do we want to go? (Defining the vision and goals)
- Where are we now? (Assessing the current situation)
- How can we get there? (outlining the steps and strategies)

Roadmaps provide a dynamic framework for understanding and managing the evolution of a business or system. Think of it as a blueprint that captures the architecture of a system, its components, and their interrelationships. This creates a common language for exploring, mapping, and communicating the development trajectory, fostering alignment and collaboration among stakeholders.

At its core, roadmapping aims to:

- Structure and visualise complex systems: By presenting multiple perspectives in a coherent visual format, roadmaps facilitate a shared understanding of the system's evolution.
- Support dialogue and collaboration: Roadmaps provide a platform for stakeholders to engage in meaningful discussions, align their efforts, and work together towards a common goal.

In essence, roadmaps serve as powerful tools for navigating complexity, fostering innovation, and guiding strategic decision-making.

4.6.2 Mode of implementation

Roadmapping is a highly adaptable method that can be tailored to suit the specific needs of any system or subject matter. This flexibility allows for a customised approach, ensuring the roadmap accurately reflects the unique challenges and opportunities of the situation at hand.

Developing a roadmap is a multi-stage process that emphasises collaboration and diverse perspectives. It requires the active involvement of key stakeholders, such as senior management, steering committees, or subject matter experts, each bringing their unique insights and expertise to the table. This collaborative approach ensures that the roadmap is comprehensive, well-informed, and aligned with the organisation's overall goals.

It's important to recognise that the quality and effectiveness of a roadmap are heavily influenced by the expertise and engagement of the individuals involved. Selecting knowledgeable and diverse participants is crucial to ensure a comprehensive and well-rounded perspective on the system's evolution.

4.6.3 Relevance of the method

Roadmaps offer a powerful visual representation that condenses complex information into a digestible format. Think of it as a "one-page" snapshot that captures the essence of a system, incorporating diverse perspectives and highlighting key milestones, dependencies, and potential challenges. This concise overview facilitates strategic dialogue and collaboration among stakeholders, fostering consensus-building, aligning actions, and identifying potential risks and tensions.

Roadmapping proves particularly valuable in situations where coordinated action and shared understanding are crucial for success. It provides a framework for bringing together diverse stakeholders, fostering collaboration, and laying the foundation for joint efforts, including financial commitments. This is especially relevant in areas like:

- Developing new standards: Roadmaps can help align industry players on common standards, facilitating interoperability and innovation.
- Advancing technologies: By outlining a clear path for technological development, roadmaps can guide research and development efforts and accelerate progress.

- Fostering innovation: Roadmaps can help organisations identify opportunities for innovation and align their efforts to bring new products and services to market.

Beyond facilitating collaboration, roadmaps offer a deeper understanding of strategy and policy. They provide a holistic view of the system, revealing the interconnectedness of internal and external objectives and enabling more effective strategic planning and decision-making.

4.6.4 Further reading

http://futureoriented.eu/courses/advanced-course-entreprenuer/lessons/module-7-lesson-5-invent-the-future-test-your-strategy-against-future-scenarios/topic/topic-3-roadmapping/

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/674209/futures-toolkit-edition-1.pdf

4.7 Scenario analysis

4.7.1 Short overview

Scenario analysis is a cornerstone of strategic foresight, providing a powerful framework for exploring the potential impact of alternative futures on a given subject. This method involves developing a set of plausible scenarios – narratives that describe different possible futures – and analysing their implications.

Scenario analysis serves two primary purposes:

- Stress-testing and future-proofing: By immersing the subject of analysis, such as strategies, insights, or solutions, in diverse future scenarios, we can assess their robustness and identify potential vulnerabilities. This involves not only considering the direct impact of events but also the cascading effects and ripple consequences. This deep dive into alternative futures helps ensure that ideas and strategies are resilient and "future-proof."
- Reframing perspectives: Scenario analysis challenges our assumptions and mental models about the present and future. By exposing us to different possibilities, it broadens our perspectives and encourages us to question ingrained beliefs. This "reframing" process enhances awareness and leads to more informed and insightful decision-making.

Ultimately, scenario analysis helps uncover hidden weaknesses and untapped opportunities. By systematically exploring alternative futures, we can identify potential challenges and leverage new possibilities, ultimately strengthening the subject of analysis.

4.7.2 Mode of implementation

Scenarios can be derived from previous project activities or sourced from external studies and research. There are many ways of developing useful and relevant scenarios of the future, varying greatly in complexity,

resources, and time required. The usual goal of the method is to examine the subject of analysis—be it a strategy, policy, or innovation—within the context of each scenario. This process helps identify which aspects of the subject are robust and resilient across different futures, and which could be vulnerable to certain disruptions. It is also very useful for ideation.

While a facilitator can guide the process and ensure effective engagement, scenario analysis can also be conducted independently. Participants with sufficient experience in strategic thinking and analysis can undertake the process on their own. However, for those less familiar with the method, or in situations where complex dynamics are at play, professional facilitation can be invaluable in guiding the analysis and maximising insights.

4.7.3 Relevance of the method

Scenario analysis is a valuable tool for strategic thinking because it:

- Uncovers hidden strengths and weaknesses: By exploring alternative futures, scenario analysis reveals previously unrecognised or underestimated strengths and weaknesses in strategies, plans, or organisations. It also highlights related opportunities and threats that might emerge in different future contexts.
- Encourages long-term thinking: Scenario analysis breaks free from the constraints of short-term thinking and encourages a broader perspective. It pushes us to consider the long-term implications of our decisions and fosters a more proactive approach to shaping the future.
- Enhances strategic decision-making: By identifying areas of vulnerability and opportunity in different future scenarios, scenario analysis helps organisations make more informed and robust strategic decisions. It enables them to prioritise goals, allocate resources effectively, and develop contingency plans to navigate uncertainty.

In essence, scenario analysis empowers organisations to move beyond reactive planning and embrace a more proactive and future-oriented approach to strategy and decision-making.

4.7.4 Further reading

Technology Foresight on Biometrics for the Future of Travel, Annex I: Technology Foresight Manual, Frontex (page 84)

https://frontex.europa.eu/assets/Publications/Research/Technology_Foresight_on_Biometrics_for_the_Future_of_Travel_Annex_I.pdf

http://foresight-platform.eu/community/forlearn/how-to-do-foresight/methods/scenario/

4.8 SWOT

4.8.1 Short overview

SWOT analysis is a valuable tool for strategic planning that provides a structured framework for assessing the internal and external factors affecting an organisation, region, or initiative. It involves identifying and categorising:

Internal factors:

- Strengths: These are the internal resources, capabilities, and advantages that give the entity a competitive edge.
- Weaknesses: These are internal limitations, deficiencies, or vulnerabilities that hinder progress or performance.

External factors:

- Opportunities: These are external conditions, trends, or events that could be leveraged to benefit the entity.
- Threats: These are external challenges, risks, or obstacles that could negatively impact the entity.

By systematically analysing these factors, SWOT analysis helps organisations align their internal resources and capabilities with the external competitive environment. This process provides valuable insights for strategic planning, enabling organisations to:

- Capitalise on strengths: Identify and leverage existing strengths to maximise opportunities.
- Address weaknesses: Develop strategies to mitigate or overcome internal weaknesses.
- Exploit opportunities: Proactively pursue opportunities that align with the entity's strengths and goals.
- Mitigate threats: Develop strategies to minimize the impact of potential threats.

An overview of these relations and the most significant internal and external factors, offers a valuable foundation for developing strategic plans and making informed decisions.

4.8.2 Mode of implementation

SWOT analysis relies on accurate and reliable data to provide a meaningful assessment of internal and external factors. Gathering this "hard data" can be a resource-intensive process, requiring both time and financial investment to collect and analyze relevant information.

The success of a SWOT analysis hinges on the expertise of the individuals involved. Participants should possess a deep understanding of the entity being analysed, whether it's a specific sector, region, organisation, or country. Their insights and knowledge are crucial for identifying and evaluating the key internal and external factors that shape the strategic landscape.

While a SWOT analysis can be conducted individually, it often benefits from a collaborative approach. Workshops or group discussions can facilitate a more comprehensive and dynamic exploration of strengths, weaknesses, opportunities, and threats, including the analysis of how these elements influence one another. This interactive format encourages diverse perspectives, fosters shared understanding, and enhances the quality of the analysis.

4.8.3 Relevance of the method

SWOT analysis serves as a powerful tool for synthesising and integrating diverse information, both historical and current. It provides a framework for bringing together existing knowledge and incorporating new insights, creating a comprehensive picture of the internal and external factors influencing an organisation or initiative.

While not strictly a foresight method in itself, SWOT analysis can be a valuable starting point for foresight discussions. It can be used to:

- Frame foresight activities: By providing a clear understanding of the current situation and potential future challenges, a SWOT analysis can help define the scope and focus of foresight activities.
- Contextualize foresight results: Foresight results, such as scenarios or emerging trends, can be analysed in the context of the organisation's strengths and weaknesses to assess their potential impact and identify strategic responses.
- Stimulate strategic dialogue: Comparing different viewpoints and perspectives within the SWOT framework can spark discussions about real threats and opportunities, leading to more robust and future-proof strategies.

Furthermore, SWOT analysis helps organisations understand their capacity to influence the future. It allows them to:

- Assess the impact of external factors: By analysing potential opportunities and threats, organisations can anticipate how external forces might affect their development and trajectory.
- Evaluate their ability to respond: By considering their strengths and weaknesses, organisations can assess their capacity to leverage opportunities, mitigate threats, and shape their future.

By comparing internal strengths and weaknesses with external opportunities and threats, organisations can gain a clearer understanding of their strategic position and identify potential pathways for future growth and success. This process can spark innovative strategy ideas and guide the development of more resilient and future-oriented plans.

4.8.4 Further reading

http://foresight-platform.eu/community/forlearn/how-to-do-foresight/methods/analysis/swot-analysis/

https://colab.alberta.ca/Mtds/Adapt/Pages/SWOT.aspx

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/674209/futures-toolkit-edition-1.pdf

4.9 Trend analysis

4.9.1 Short overview

Trend analysis is fundamental for foresight, sharing equal importance with methods like scenario analysis and expert consultations. While the concept of a "trend" is widely applied across diverse fields, from mathematics and statistics to finance and fashion, its meaning can vary considerably depending on the context.

Generally, a trend refers to a consistent pattern of change over time, indicating an increase or decrease in a particular phenomenon, or a shift in the rate of that change. However, unlike trends in fields like physics or statistics, which are often objectively measurable, trends in the social sphere are more nuanced and subjective.

Analysing social trends presents unique challenges. These trends are not simply pre-existing, objective phenomena waiting to be discovered. Instead, they are often constructs shaped by the perspectives, interpretations, and prior knowledge of the analysts studying them. Think of social trends as simplified representations of complex social dynamics, serving as tools to facilitate understanding, discussion, and decision-making about the future.

Therefore, conducting trend analysis in the social sphere requires careful consideration and critical thinking. Analysts must be mindful of their own biases and assumptions, and strive to interpret trends in a balanced and objective way. By acknowledging the subjective element inherent in social trend analysis, we can leverage this method effectively to gain valuable insights into potential future developments.

4.9.2 Mode of implementation

The initial phase of trend analysis involves identifying relevant trends through comprehensive desk research. This entails delving into research publications, reports, and other relevant documents to uncover patterns and shifts related to the issue at hand. Quantitative data from bibliometric and patent analysis can further enrich this process, providing valuable insights into research activity and technological advancements.

Once gathered, this information is organised and categorised in relation to the organization's areas of activity. A common framework for clustering trends is the STEEP analysis, which categorises factors into five key areas: Social, Technological, Economic, Environmental, and Political. This structured approach helps identify trends within each domain and understand their potential impact on the organisation.

The next stage involves engaging experts to assess the identified trends and determine their relevance and potential impact on the organisation. This can be achieved through interactive workshops or structured

brainstorming sessions, where experts collectively analyse and prioritise trends. Alternatively, a survey-based approach, such as the Delphi method, can be employed to gather expert opinions remotely and systematically.

By combining thorough desk research with expert assessment, organisations can gain a comprehensive understanding of relevant trends and their potential implications for strategic planning and decision-making.

4.9.3 Relevance of the method

Trend analysis provides a structured approach to understanding current trends and their potential implications for the future. It serves as a springboard for strategic analysis, enabling decision-makers to:

- Identify future trends: By extrapolating current trends and considering potential disruptions, organisations can anticipate future developments and prepare for emerging challenges and opportunities.
- Uncover opportunities and threats: Trend analysis helps identify potential opportunities to leverage and threats to mitigate, allowing organisations to proactively shape their future.
- Enhance strategic advantage: By understanding the evolving landscape, organisations can identify new sources of competitive advantage and adapt their strategies to stay ahead of the curve.

4.9.4 Further reading

http://futureoriented.eu/courses/module-3/lessons/module-3-lesson-2-methods-for-trends-identification-and-analysis/topic/topic-2-trend-analysis/

https://css.ethz.ch/content/dam/ethz/special-interest/gess/cis/center-for-securities-studies/pdfs/RR-Reports-2021-StrategicForesight.pdf

4.10 Wild cards (hyper- & anti- trends identification)

4.10.1 Short overview

Wild Cards are low-probability, high-impact events that can significantly disrupt trends and reshape the future. They are often unexpected and can have far-reaching consequences for individuals, organisations, and societies. Wild Card analysis aims to identify and assess these potential disruptions, develop strategies for preparedness or mitigation, and even explore opportunities to leverage positive Wild Cards.

4.10.2 Mode of implementation

The Wild Card method involves a four-step process:

- Identification: Brainstorming, expert interviews, surveys, historical analogies, and science fiction analysis can be used to identify potential Wild Cards.

- Assessment: A framework is used to assess the potential impact of each Wild Card on a target group, considering factors like vulnerability, timing, opposition, reach, outcome, and rate of change. This helps prioritise which Wild Cards to focus on.
- Monitoring: This involves identifying and tracking weak signals and precursor events that may indicate the increasing likelihood of a Wild Card occurring.
- Developing Options for Action: This involves exploring strategies to mitigate negative impacts, leverage positive impacts, or even influence the probability of a Wild Card occurring. This may require "out-of-the-box" thinking, creativity, and exploring unconventional approaches.

4.10.3 Relevance of the method

Wild Card analysis helps individuals and organisations anticipate and prepare for unexpected disruptions, increasing their resilience and adaptability. By considering potential disruptions, it can lead to more robust and flexible strategies that can better withstand unexpected events. Exploring potential Wild Cards can spark creativity and lead to innovative solutions and new ways of thinking. Wild Card analysis complements traditional risk management by considering low-probability, high-impact events that may be overlooked by conventional methods.

4.10.4 Further reading

Petersen, John L. Out of the Blue, Wild Cards and Other Big Surprises. The Arlington Institute 1997, 2nd ed. Lanham: Madison Books, 1999.

Steinmüller, Karlheinz. "The Future as Wild Card – Towards a Methodology of the Unpredictable." In: Beyond 2000. Challenges for Futures Studies. Documentation of the SFZ Summer Academy 1996, SFZ-WerkstattBericht 20, Gelsenkirchen 1997, pp. 98-104.

5. Main phases of the strategic foresight process of MASTT2040 project

Overall, there are six main stages in the strategic foresight process: framing, scanning, forecasting, visioning, planning and acting (Hines, Bishop 2006).

- Framing provides guidelines regarding the rationale, audience and objectives of strategic foresight.
- Scanning provides guidelines concerning the system, history and context; it determines how to scan information regarding the future of the topic or organisation.
- Forecasting uses the information obtained through scanning and outlines guidelines regarding drivers, uncertainties and alternatives.
- Visioning provides guidelines which focus on analysing the implications of the forecasts and envisioning (desired) outcomes for the organisation.
- Planning provides guidelines that develop the strategy and options for carrying out the vision.

- Acting provides guidelines for communicating the results, developing action agendas, and institutionalising strategic foresight by the deployment of monitoring and update systems.

These somewhat general steps have been tailored to meet the needs and the indicated objectives of the MASTT2040 project (Fig. 1).

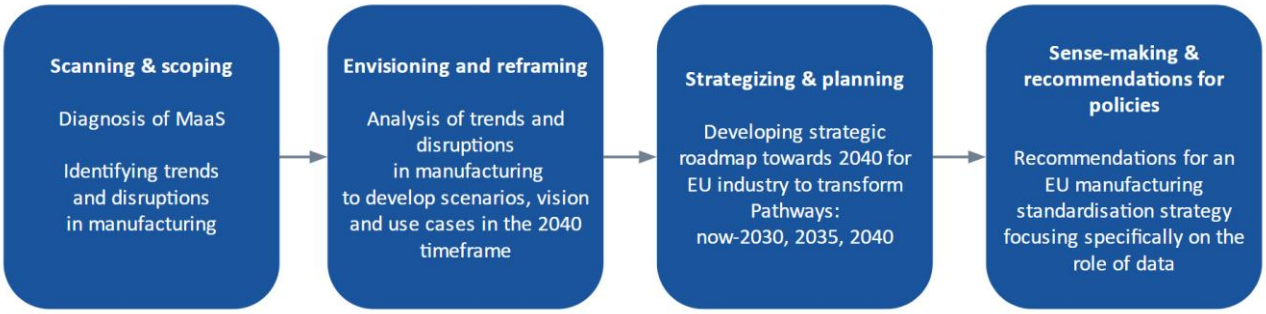

Fig.1. Main phases of MASTT2040 strategic foresight approach

5.1 Scanning and scoping

The goal of this step is to collect relevant information about the external environment of the topic under study. The collected information usually falls into three main categories:

- Drivers, which are influential forces of changes that are currently shaping or have the capacity to shape or transform a given system. They can take on different states and thus affect a system in many ways, therefore are often called uncertainties.
- Trends, which depict historical change over time (up until the present). They are changes that are measurable/observable, which means that quantitative or qualitative data can be collected, which can illustrate the historical pattern. They have a clear direction of change and dynamics (increasing, decreasing, holding steady).
- Signals of change, an early indication that disruptive change could be underway.

In the MASTT2040 context the scanning and scoping stage enable the project team to establish the foundational elements for scenario development and roadmapping. This involves:

- Leveraging data and knowledge from desk research to develop a framework model of the manufacturing industry. This model, informed by IDI results and validated through stakeholder engagement, captures key strategic aspects of the industry, including both MaaS (Manufacturing-as-a-Service) and Centralised Manufacturing approaches.
- The framework model serves as the basis for analysing the primary forces shaping the EU's manufacturing industry and their connection to the goals of the Twin Transition (green and digital transitions).

- Findings from research on use cases and best practices further refines the model, providing practical context and real-world insights.
- The model is being enriched by considering external factors that could influence the future of the manufacturing industry, such as emerging technologies, innovative business models, and anticipated geopolitical shifts.

By comprehensively scanning the internal and external landscape of the EU manufacturing industry, this stage aims to create a robust foundation for subsequent foresight activities, enabling the development of insightful scenarios and effective roadmaps.

5.1.1 Main phases of analysis

Analysis of the best practices and use cases

The process begins with a comprehensive scan of existing MaaS cases and best practices. These cases are being analysed to understand their underlying concepts, stakeholder relationships, key success factors, limitations, and assumptions. Early stakeholder engagement through In-Depth Interviews (IDIs) provides valuable feedback and insights.

Recognising that existing cases may not encompass all aspects of MaaS, the process then engages stakeholders in MaaS and the Circular Economy (CE) to explore how these cases can be extended and adapted. This collaborative exploration focuses on developing future MaaS solutions that support distributed production models and advance circularity and sustainability.

This process of scanning, analysing, and collaboratively exploring MaaS cases provides a robust foundation for understanding the current landscape and envisioning the future of MaaS in manufacturing. This approach can be adapted and applied to other projects exploring the future of manufacturing, ensuring a comprehensive and stakeholder-informed perspective.

Identification of trends and drivers shaping EU manufacturing industry and future of MaaS

To gain a comprehensive understanding of this evolving landscape, the process should employ a thorough assessment of the current state of the industry. This can be achieved by building on existing knowledge, leveraging available research, reports, and insights from previous projects to establish a foundation of understanding. Additionally, conducting extensive desk research and horizon scanning can involve a comprehensive review of relevant documents, including recent projects, roadmaps, future visions, EU industrial policies, and strategies related to the Twin Transition. This helps identify the main forces shaping the manufacturing industry today, including trends, drivers, and weak signals. Finally, analysing key forces and relationships allows for an assessment of the identified forces and their potential impact on the goals of the Twin Transition, considering both MaaS and Centralised Manufacturing approaches.

By following this structured approach, the process can effectively analyse the current landscape and map the long list of the most impactful phenomena, which should guide the next phase of the analytical process: prioritisation of the key insights.

Identification of strengths, weaknesses, enablers and blockers of MaaS

This stage involves a deep dive into the factors that influence the adoption and impact of MaaS within the manufacturing industry. It aims to identify the strengths, weaknesses, enablers, and blockers that shape the MaaS landscape. This analysis encompasses a multi-faceted approach, beginning with an evaluation of the inherent strengths and weaknesses of MaaS itself. This includes assessing the advantages and disadvantages of MaaS compared to traditional manufacturing models, considering factors such as flexibility, resource efficiency, cost-effectiveness, and scalability. The analysis then extends to identifying external factors that enable or hinder MaaS adoption. This involves analysing the broader ecosystem in which MaaS operates, including environmental impacts, technological advancements, regulatory frameworks, economic conditions, and societal attitudes. Furthermore, the analysis pinpoints specific barriers to MaaS implementation, which may include challenges related to data security, standardisation, intellectual property, skills gaps, or resistance to change within organisations. Finally, this stage focuses on uncovering opportunities to accelerate MaaS adoption. This involves identifying potential catalysts for MaaS growth, such as supportive policies, collaborative initiatives, and innovative business models.

The SWOT analysis of the MaaS approach aims to provide an objective assessment of its potential to enable the twin transition, identifying key strengths, weaknesses, opportunities, and threats, without presenting it as the sole or definitive solution.

5.1.2 Methods and tools supporting implementation

- Desk research
- SWOT analysis
- Brainstorming workshop

5.1.3 Key outputs

- Scope of the foresight study
- MaaS definition
- Long list of trends
- SWOT: conclusions

5.1.4 Templates

- Template for desk research using (G)PESTLEI framework

Trend influencing the future of manufacturing
name

(Geo)Political	•
Economical	•
Ethical	•
Social	•
Technological	•
Legal	•
Environmental	•
Industrial	•
Fostering Maas? (scale from -2 to 2)*	
Fostering centralized manufacturing? (scale from-2 to 2)*	
Fostering the twin transition? (decarbonization, digitisation, sustainability, circularity) (scale from -2 to 2)*	

*Scale:
-2 - trend is extremely harmful
0 - trend is neutral
2 - trend could be a major driver

- Template for SWOT analysis

Element of SWOT analysis	
name	
Does it apply: -to MaaS, -to centralised manufacturing, -or perhaps to both these concepts?	
What (G)PESTLEI category does the element fall into? (choice 1)	
What (G)PESTLEI category does the element fall into? (choice 2, if needed)	
Strength? Weakness?	

Enabler? Blocker?	
Strength? Weakness? Enabler? Blocker? (choice 2, if needed)	
Fostering sustainability of the EU industry while minimizing resource use and emissions? (scale from -2 to 2)*	
Fostering digitization of the EU industry? (scale -2 to 2)*	
Boosting competitiveness of the EU? (scale from -2 to 2)*	
Fostering the strategic autonomy of the EU? (scale from -2 to 2)*	

*Scale:
-2 - element is extremely harmful
0 - element is neutral
2 - element could be a major driver

5.2 Envisioning and Reframing

The objective of the Envisioning and Reframing stage is to develop a comprehensive foresight perspective on the future of manufacturing in the context of the Twin Transition. This involves:

- Trend analysis and prioritisation: Trends identified in the previous stage are refined and synthesized into a core set, which are then evaluated through a survey to determine their impact on four key factors driving the Twin Transition: digitization, decarbonization, circularity, and sustainability. This analysis produces a prioritised list of crucial trends likely to influence the Twin Transition in EU manufacturing, with a focus on the interplay between MaaS and Centralised Manufacturing approaches.
- Delphi survey and assessment of trend disruptions: A real-time Delphi survey follows, which focuses on the assessment of probability and impact of trend discontinuities. The Delphi survey results complement the trend analysis by identifying key uncertainties shaping the future of the manufacturing domain.
- Scenario building: An inductive approach is being used to construct exploratory scenarios for the future of manufacturing. These scenarios explore the implications of key trends and their potential disruptions providing a high-level overview of the future strategic environment of manufacturing and

a framework for identifying hypothetical MaaS use cases. In particular, the scenarios encompass the following elements:

- Trends, which might have the highest influence on the future of manufacturing, in this:
  - trends, which might have positive influence on Twin Transition;
  - trends, which might have negative influence on Twin Transition
- Phenomena, which are likely to disrupt key trends:
  - "positively"
  - "negatively"

By combining trend analysis, a Delphi survey and scenario building, this stage aims to provide a robust and nuanced vision of the future of manufacturing, enabling informed decision-making and strategic planning in the context of the Twin Transition.

5.2.1 Main phases of analysis

In-depth analysis of trends and identification of key uncertainties

This stage focuses on refining and prioritising the trends identified in earlier stages to create a focused set of drivers for scenario building. Once the long list of trends, drivers and signals observed in the EU manufacturing domain are collected and clustered according to (G)PESTLEI categories, their processing and prioritisation can be organised in the following way:

- Internal brainstorming session: Evaluation of the (G)PESTLEI list to rank the trends based on their potential strength of influence on future manufacturing in 2040 perspective. This results in a list of ranked trends, graded in terms of their potential influence on the future of manufacturing.
- Internal scoping session: Analysing the results of the ranking session to further narrow down the list by focusing on the most impactful ones and merging those that were similar to one another. This usually results in a final, manageable list of trends (ideally up to 20-25), which form the core input to the next analytical phase.

The next step is to engage with stakeholders representing the industrial manufacturing and MaaS communities in a structured discussion to assess the potential impact and susceptibility to change of each trend. This collaborative process helps identify the most crucial trends that are likely to shape the future of the industry. Then, stakeholders are guided to anticipate potential disruptions that could accelerate or decelerate the identified trends. These disruptions might stem from various sources, including evolving geopolitical contexts, technological breakthroughs, or shifts in consumer behavior. This analysis leads to the creation of alternative trend development paths, including "hyper-trends" (events accelerating trends) and "anti-trends" (events decelerating or reversing trends). Finally, based on the analysis of potential disruptions and alternative trend paths, the initial long list of trends is narrowed down to a manageable number of the most crucial ones. These prioritised trends serve as the building blocks for scenario development.

This process ensures that the scenario building exercise is grounded in a robust and stakeholder-informed understanding of the key forces shaping the future of manufacturing. By engaging stakeholders in a collaborative analysis of trends and potential disruptions, projects can develop more insightful and relevant scenarios that effectively explore the range of possible futures for the industry.

Prioritisation of trends and signals of change in MaaS

This stage involves a detailed assessment of the prioritised trends to understand their potential impact on the future of manufacturing. This process can be adapted to other projects and includes the following steps, starting with the shortlisted trends identified in the previous stage through stakeholder consultation and criticality assessment. These trends represent the most crucial forces likely to shape the future of the manufacturing industry. Next, a real-time Delphi survey is conducted with a preselected group of experts to evaluate the probability and impact of each trend. This survey, facilitated by an online Delphi platform like the 4CF HalnyX, allows experts to collaboratively assess the potential implications of each trend on achieving strategic goals, such as those related to the Twin Transition. The Delphi survey results are then analysed using probability-impact analysis and risk matrix analysis. This helps quantify the potential risks and opportunities associated with each trend, considering their likelihood and potential impact on different manufacturing models, such as distributed MaaS versus centralised manufacturing. Finally, the findings from the Delphi survey and risk analysis are integrated with the previously identified trends and their foreseeable developments. This comprehensive analysis provides a deeper understanding of the potential implications of each trend and informs the development of robust strategies and roadmaps.

By systematically assessing the probability and impact of key trends, this process enables a more nuanced understanding of the potential risks and opportunities associated with different manufacturing models and future scenarios. This approach can be applied universally to other projects focused on the future of manufacturing, ensuring that strategic decisions are informed by a robust and data-driven assessment of potential future trends and their implications.

Co-creating MASTT2040 scenarios with stakeholders

This stage focuses on constructing scenarios to explore alternative futures for the manufacturing industry, providing a crucial foundation for strategic planning and decision-making. This process unfolds in a structured manner, starting with clearly defining the purpose and scope of the scenario building exercise. The general goal of this stage is to develop scenarios that would be[1]: plausible: challenging; non-obvious, distinct, comprehensive and internally coherent.

Scenario development is started with drafting scenario outlines, the bedrock of which can be based on the outcomes of the Delphi Study, encompassing both quantitative rankings and qualitative expert commentary. It's also important to integrate relevant insights and outputs from previous stages of the project, including prioritised trends, potential disruptions, and stakeholder perspectives. This ensures that the scenarios are grounded in a robust understanding of the forces shaping the future of the analysed topic. In the selection

[1] These scenario characteristics are described in more detail in Del 2.1.

of the defining factors for each scenario outline, the following guiding criteria[2] should be used: emphasis on uncertainty; impact on the Twin Transition; internal coherence.

Through this methodical approach, one can develop scenario outlines that are not only plausible and challenging but also capable of sparking insightful dialogue and strategic foresight regarding a wide range of plausible futures.

The process then moves to engaging stakeholders in a collaborative workshop to co-create narratives that further explore alternative futures for the industry, using the outlines as a starting point. These narratives should extend to a relevant future timeframe, such as 2040, and consider the potential implications of the identified trends and disruptions. From this collaborative process, a minimum of three scenarios should be generated, each being plausible, transformative, and useful for strategic planning purposes. Finally, tools like the Futures Wheel are utilised to explore the potential consequences and implications of each scenario, then described in a structured manner, with a clear distinction between certain areas of interest or categories.

This structured approach to scenario building provides a valuable framework for strategic planning and decision-making in the manufacturing industry. By engaging stakeholders in a collaborative process and considering a range of plausible futures, projects can develop robust strategies that are resilient to uncertainty and effectively address the challenges and opportunities that lie ahead.

Sense-making to delineate future use cases of MaaS

This stage leverages the developed scenarios to explore potential future applications and implications of MaaS within the manufacturing industry. This process comprises the following steps, starting with synthesising the insights from the exploratory scenarios developed in the previous stage. These scenarios provide a comprehensive overview of the potential future landscape for the manufacturing industry, including key trends, uncertainties, and disruptions. Next, a scenario-impact analysis is conducted to assess the potential implications of each scenario for the adoption and evolution of MaaS. This analysis should consider both the opportunities and challenges that MaaS may encounter in each scenario. Based on the scenario analysis, hypothetical yet plausible future use cases for MaaS are identified. These use cases should be grounded in the specific opportunities and challenges presented by each scenario, demonstrating how MaaS can contribute to addressing future needs and achieving strategic goals, such as those related to the Twin Transition. Finally, a strategic analysis of the collected insights is conducted to formulate detailed descriptions of the future use cases and applications of MaaS. This analysis should consider the potential benefits, challenges, and requirements for implementing each use case.

This structured process allows for a comprehensive exploration of the potential future applications of MaaS within the manufacturing industry. By grounding the analysis in diverse scenarios and engaging in strategic foresight, projects can develop a robust understanding of how MaaS can contribute to the future of manufacturing and identify promising pathways for its development and adoption.

[2] Guiding criteria are elaborated further in Del 2.1

5.2.2 Methods and tools supporting implementation

- Online survey (to assess key trends)
- Delphi survey (to assess key trends' disruptions)
- Wild cards
- Brainstorming workshop (using PnyX software)[3]
- Scenario workshop

5.2.3 Key outputs

- List of key trends
- List of key trends' disruptions
- 4 scenarios
- List of use-cases of MaaS

5.2.4 Templates

- Trend assessment survey template

Trend name	Trend's strength of influence on the future of manufacturing until 2040 (0-10 scale)	Trend's ability to stimulate various models of manufacturing (on a scale -3; + 3)*	Trend's ability to foster the Twin Transition (sustainability, circularity, digitization, decarbonisation)**

*Scale:
-3 - continuation of this trend is a major obstacle to further use of the model
0 - continuation of this trend is neutral to further use of the model
3 - continuation of this trend is extremely favourable to the wider use of the model

**Scale:
-3 - trend is extremely harmful to the goals of the Twin Transition
0 - trend is neutral to the goals of the Twin Transition
3 - trend could be a major driver of the Twin Transition

[3] The 4CF PnyX is an interactive debate platform designed to enhance brainstorming sessions, strategic planning, and product ideation. It facilitates structured, gamified discussions, and visualizes arguments in a clear and accessible format. By providing a structured framework for exploring complex topics and generating ideas collaboratively, 4CF PnyX empowers users to navigate intricate issues and foster creative problem-solving. Its intuitive interface and streamlined workflow allow participants to focus on generating insights and developing solutions. Designed for online workshops, 4CF PnyX supports dynamic discussions and collaborative solution development.

- Template to identify trend disruptions

Trend name	Name of event n, which could accelerate the trend	Name of event n+1, which could accelerate the trend	Name of event n, which could decelerate or reverse the trend	Name of event n+1, which could decelerate or reverse the trend

- Delphi survey template

Delphi thesis	Probability* (on a scale 0-100 (%))	Impact** (on a scale -3; + 3)

*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

- Future of manufacturing: scenario template

Political Context of Manufacturing
Description
Economic Context of Manufacturing
Description
Environmental Context of Manufacturing
Description
Social Context of Manufacturing
Description
Technological Context of Manufacturing
Description
Industrial Context of Manufacturing

Description
Forms of manufacturing
Description

- Scenario analysis: MaaS use cases template

MaaS use cases				
How does Manufacturing-as-a-Service fit in this scenario? Are there any particular ways and rules according to which MaaS operates in this scenario?	Are there any opportunities that arise in this scenario for MaaS manufacturers?	What challenges manufacturers operating or willing to operate under the frames of MaaS model face 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?

- Scenario analysis: MaaS vision template

MaaS vision		
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?

5.3. Strategizing and planning

The objective of the Strategizing and Planning stage is to develop and select strategies that enable the sustainable transformation of the manufacturing industry by exploiting opportunities and managing risks identified in previous stages. This involves:

- Roadmapping for Industry Transformation: Conducting two collaborative roadmapping workshops to outline short-term (5 years), medium-term (10 years), and long-term (15 years) pathways for the industry to adapt to future scenarios and maximise the impact of MaaS.
- Detailed MaaS Use Case Analysis: Further detailing MaaS use cases identified earlier, including information on their potential contributions to circularity, decarbonisation, and sustainability targets, and assessing investment and standardisation needs.
- Industry Strategy and Action Plan Development: Elaborating an Industry Strategy and Action Plan that prioritises actions to maximise the desired impact of MaaS in Europe. This plan will be validated by stakeholders from industry, associations, and standards bodies and widely disseminated to ensure broad uptake and implementation in industry and policy.

By combining roadmapping with detailed action planning and stakeholder validation, this stage aims to translate foresight insights into concrete strategies and actions that drive the sustainable transformation of the manufacturing industry and maximise the benefits of MaaS.

5.3.1 Main phases of analysis

Roadmapping MaaS for twin transition

This stage focuses on translating foresight insights into strategic roadmaps that guide the development and adoption of MaaS within the manufacturing industry. This process involves several steps, starting with analysing the scenarios developed in previous stages. This analysis aims to identify the aspects that have the highest impact on key goals, such as circularity, sustainability, resilience, and human-centered manufacturing. By assessing potential correlations and cross-impacts between these aspects across different scenarios, a comprehensive understanding of the opportunities and challenges for MaaS adoption can be achieved. Based on this analysis, the next step is to select the aspects that have a high impact on one or more goals without negatively affecting others. These aspects will form the foundation for developing pathways that maximise the positive impact of MaaS on the manufacturing industry's transition towards sustainability and digitalisation.

A roadmapping exercise is then conducted, focused on three time frames (present-2030, 2030-2035, 2035-2040). This involves analysing the selected high-impact aspects across various categories relevant to MaaS, such as drivers, markets, research needs, digital technologies, standards, and investments. To enrich this process, key stakeholders from industry, associations, standardisation bodies, academia, and networks are engaged in two collaborative workshops. These workshops facilitate a shared understanding of the challenges and opportunities associated with MaaS adoption and contribute to the development of a robust roadmap. The culmination of this stage is the development of a comprehensive roadmap that identifies priority areas and gaps that need to be addressed to achieve the identified pathways for MaaS. This roadmap will highlight the actions and strategies required to maximise the potential impact of MaaS on achieving the defined goals, such as circularity, sustainability, and decarbonisation.

This structured approach to roadmapping ensures that strategic planning for MaaS is grounded in a comprehensive understanding of future scenarios and stakeholder perspectives. By analysing high-impact aspects and engaging in collaborative workshops, the process can develop effective roadmaps that guide the manufacturing industry towards a more sustainable and digitally-driven future.

Pathways to impact for Future MaaS use cases

This stage focuses on refining and elaborating the identified MaaS use cases to assess their potential impact on sustainability, decarbonisation, and circularity within the manufacturing industry. This process involves a series of steps. First, a virtual workshop is conducted to further develop and concretise the MaaS use cases identified in previous stages. Recognising that these initial use cases may have a limited impact on sustainability goals, the workshop aims to explore how these use cases can be enhanced to contribute more significantly to decarbonisation, circularity, and overall sustainability. During the workshop, a minimum of five use cases are developed, and participants assess their degree of achievability, considering the challenges associated with their implementation. Additionally, participants evaluate the investment levels required to realise these use cases and identify specific gaps in standardisation, research, and other areas that need to be addressed. Furthermore, stakeholders collaboratively identify key technologies and cross-cutting aspects, such as digital risks and opportunities, that may require standardisation at the international level.

This collaborative and iterative process ensures that the identified MaaS use cases are not only refined but also assessed in terms of their potential impact on sustainability goals and their feasibility for implementation. By engaging stakeholders in this analysis and identifying key requirements and challenges, the process can develop a more robust understanding of how MaaS can contribute to a more sustainable and innovative manufacturing industry.

Industry Strategy and Action Plan for future MaaS

This stage focuses on developing a comprehensive strategy and action plan to guide the adoption and maximise the impact of MaaS. This process involves a series of steps. First, building upon the key exploitation paths for MaaS identified in previous stages, along with insights from best practices, future trends, and data standardisation gaps, an Industrial Strategy and Action Plan is created. This plan outlines priority actions for the short, medium, and long term, addressing policy and standardisation gaps that will be further elaborated in subsequent stages. The core aim is to clearly define pathways for maximising the impact of MaaS within Europe. Next, an online Industrial Validation Meeting is organised, bringing together a diverse group of stakeholders from across Europe, including representatives from academia, industry (particularly SMEs), and the broader MaaS community. During this meeting, the results of previous analyses and the draft Industrial Strategy and Action Plan are presented to gather feedback and ensure alignment with stakeholder perspectives. Participants' views are actively sought to validate and refine the plan, addressing identified gaps in areas such as policy, data standardisation, and strategic investment. Finally, the finalised Industrial Strategy and Action Plan is widely disseminated to promote the adoption of MaaS in the industry and inform future funding programs, and other relevant initiatives.

This structured approach ensures that the Industrial Strategy and Action Plan is grounded in robust analysis, stakeholder input, and a clear vision for the future of MaaS in Europe. By actively engaging the MaaS community and disseminating the plan widely, this process aims to accelerate the adoption of MaaS and maximise its potential to drive innovation and sustainability within the manufacturing industry.

5.3.2 Methods and tools supporting implementation

- Roadmapping
- Scenario analysis
- Brainstorming workshop
- Prob-Imp analysis

5.3.3 Key outputs

- MaaS Roadmap and Pathways towards twin transition
- MaaS Industry Strategy and Action Plan

5.3.4 Templates

- Roadmapping template

Strategic Gap				
Strategic Objective 1				
Timeline	Key activities *(layer1)*	*Layer 2*	*Layer 3*	*Layer 4*
Until 2030				
2031-2035				

2036-2040				

5.4. Collaborative sense-making and recommendations

The objective of the Collaborative Sense-Making and Recommendations stage is to translate foresight insights and strategic plans into concrete actions and recommendations for standardisation in the manufacturing industry. This involves:

- Standardisation Gap Analysis: Analysing the project results and assessing their compliance with current regulations to identify priority areas for standardisation in the short-term (5 years), mid-term (5-10 years), and long-term (10+ years).
- Collaborative Workshop with SDOs: Engaging with Standards Development Organisations (SDOs) in an online event to discuss, assess, and validate suggestions for closing standardisation gaps and draft recommendations for a manufacturing standardisation strategy.
- Stakeholder Engagement and Dissemination: Building a strong foundation for stakeholder involvement through effective communication and dissemination measures.

By combining detailed analysis with collaborative workshops and broad stakeholder engagement, this stage aims to ensure that the foresight insights are translated into actionable recommendations for standardisation, ultimately contributing to the sustainable transformation of the manufacturing industry.

5.4.1 Main phases of analysis

Validation & refinement of the findings

This stage focuses on developing a comprehensive strategy and action plan to guide the adoption and maximise the impact of innovative approaches, such as MaaS, within the manufacturing industry. This process involves a series of steps, starting with the creation of an Industrial Strategy and Action Plan. This plan builds upon the key exploitation paths identified in previous stages, incorporating insights from best practices, future trends, and identified data standardisation gaps. The plan outlines priority actions for the short, medium, and long term, addressing policy and standardisation gaps that will be further elaborated in

subsequent stages. The core aim is to clearly define pathways for maximising the impact of the innovative approach within the industry. Next, an online validation meeting is organised, bringing together a diverse group of stakeholders from across the industry, including representatives from academia, various sized businesses, and the broader community related to the innovative approach. During this meeting, the results of previous analyses and the previously developed Industrial Strategy and Action Plan are presented to gather feedback and ensure alignment with stakeholder perspectives. Participants' views are actively sought to validate and refine the plan, addressing identified gaps in areas such as policy, data standardisation, and strategic investment. Finally, the finalised Industrial Strategy and Action Plan is widely disseminated to promote the adoption of the innovative approach within the industry and inform future funding programs, innovation hubs, public-private partnerships, and other relevant initiatives.

This approach ensures that the Industrial Strategy and Action Plan is grounded in robust analysis, stakeholder input, and a clear vision for the future of the innovative approach within the industry. By actively engaging the relevant community and disseminating the plan widely, this process aims to accelerate the adoption of the innovation and maximise its potential to drive growth and sustainability within the manufacturing industry.

Engaging SDOs in identifying priority areas for work

This stage focuses on analysing the data standardisation needs of innovative manufacturing approaches, such as MaaS, and engaging with relevant standardisation bodies to ensure alignment and future-proof solutions. This process involves a series of steps. It begins with a detailed analysis of the data standardisation needs identified in previous stages, considering the specific requirements and challenges of the innovative approach. Next, key Standards Development Organisations (SDOs), both formal and informal, are engaged through consultations and workshops. This includes collaborating with relevant actors in the field, such as DIN, VDE, VDMA, oneM2M, W3C, IEC, ISO, and other organisations involved in standardisation efforts for various technologies and domains. The aim of this engagement is to assess whether existing standardisation activities are sufficient to meet the needs of the innovative approach or if modifications or new initiatives are required. The ultimate goal is to proactively influence ongoing standardisation activities to ensure they support the successful adoption and implementation of the innovative approach. Finally, the identified standardisation needs are widely disseminated to relevant stakeholders active in standardisation, fostering collaboration and awareness within the broader community.

This structured approach ensures that standardisation efforts are aligned with the specific needs of innovative manufacturing approaches. By engaging with SDOs and disseminating information widely, this process aims to create a supportive standardisation landscape that facilitates the adoption and maximises the impact of innovations within the manufacturing industry.

Recommendations for Industrial Data Standardization in Manufacturing for future MaaS

This stage focuses on developing recommendations for standardisation in the manufacturing industry, addressing both short-term and long-term needs. This process involves a series of steps. First, based on the knowledge gathered in previous stages, including the analysis of standardisation gaps and engagement with

Standards Development Organizations (SDOs), recommendations are formulated for closing these gaps in the near-term (5 years), mid-term (5-10 years), and long-term (10+ years). Recognising that the creation of new standards is a time-consuming process, the recommendations primarily highlight the need for new standardisation activities, particularly those that support the long-term development of innovative approaches like MaaS. These recommendations are then aligned with the Rolling Plan for standardisation, a dynamic document that is reviewed annually based on input from the European Commission and the Multi-Stakeholder Platform on ICT standardisation (MSP). To facilitate this alignment, the project leverages its strong links with the MSP, a group of experts that advises the Commission on ICT standardisation matters. This engagement with the MSP, composed of Member States, EFTA countries, SDOs, industry representatives, SMEs, and societal stakeholders, ensures that the recommendations are effectively communicated and considered within the broader European standardisation landscape.

This structured approach ensures that standardisation recommendations are not only comprehensive but also aligned with existing standardisation processes and informed by expert input. By actively engaging with the MSP and emphasising long-term standardisation needs, this process aims to create a future-proof standardisation landscape that supports the successful adoption and implementation of innovative approaches within the manufacturing industry.

5.4.2 Methods and tools supporting implementation

- Brainstorming workshop
- Trend analysis

5.4.3 Key outputs

- Standardisation Analysis Report
- Policy recommendations for standardisation

6. Conclusions

This strategic foresight manual offers a comprehensive and adaptable framework for navigating the complexities and uncertainties that lie ahead. By embracing the principles and methodologies outlined in this manual, stakeholders can enhance their ability to anticipate change, make informed decisions, and shape a future that aligns with their goals and aspirations.

The insights and tools provided in this manual are not limited to the manufacturing industry; they can be applied across various sectors and domains. By embracing a foresight-driven approach, individuals and organisations can proactively position themselves for success in an ever-changing world. As we move forward, strategic foresight will become an increasingly essential tool for navigating the complexities of the future and creating a more resilient and sustainable world.

7. Literature

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