Interreg CENTRAL EUROPE

Co-funded by the European Union

GREENE 4.0

O1.3 – Tested User Acceptance Model

General output

Date of Report: 31.08.2024

Document Control Sheet

Work package Number	1
Work package Title	Design, test and deploy user acceptance model
Activity Number	1.3
Activity Title	Develop user acceptance model
Deliverable Number	D1.3.1
Deliverable Title	User Acceptance Model
Dissemination level	PU
Main author	Lea Lebar, Stefan-Cataline Ilie, Nardoni Marusa (University of Ljubljana)
Contributors	All partners
Quality Assurance	Marko Močnik

Versioning and Contribution History

Version	Date	Author/Editor/Reviewer	Contributors	Description/Comments
_D01	15.2.2024	Lea Lebar, Catalin Ilie, Maruška Nardoni, Vesna Dolničar (PP4)		Draft user acceptance model
_D02	20.2.2024	Lea Lebar, Catalin Ilie, Maruška Nardoni, Vesna Dolničar (PP4)	All partners	Revision by project partners
_D03	23.5.2024	Lea Lebar, Catalin Ilie, Maruška Nardoni,	All partners	Update of the document based on first testing results
_D04	15.8.2024	Lea Lebar, Catalin Ilie, Maruška Nardoni,	All partners	Update of the document based on second iteration of testing results
_D05	25.8.2024	Lea Lebar, Catalin Ilie, Maruška Nardoni (PP4)	All partners	Revision by project partners
_D06	28.8.2024	Marko Močnik (LP)		Quality check
_F01	31.8.2024	Lea Lebar, Catalin Ilie, Maruška Nardoni (PP4)		Final form of the document
Due date of output		31.08.2024		

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A. Introduction

Central Europe manufacturing companies face unprecedented challenges and opportunities. The twin forces of digitalization and sustainability are reshaping the industry, demanding that companies adapt quickly or risk being left behind. This output, based on an extensive pilot testing study of GREENE 4.0 User Acceptance Model performed on 68 manufacturing SMEs across seven Central European countries (Slovenia, Hungary, Italy, Czech Republic, Austria, Germany and Poland), aims to provide manufacturing businesses with valuable insights and practical guidance for navigating these transformative changes.

Digitalization is no longer a luxury; it's a necessity. From smart factories and IoT-enabled equipment to AI-driven predictive maintenance and blockchain-secured supply chains, digital technologies are revolutionizing every aspect of manufacturing. Companies that embrace these technologies are seeing important improvements in efficiency, productivity, and innovation capacity.

Consider the case of a medium-sized metal fabrication company in Germany that participated in our study. After implementing a comprehensive digital production management system, they saw a 30% increase in productivity and a 25% reduction in waste within just six months. Their CEO remarked, "Digitalization has transformed our business. We're now able to compete with much larger companies on both quality and price."

Similarly, the green transition is not just about compliance or corporate social responsibility - it's becoming a key factor in competitiveness. Consumers and B2B customers alike are increasingly demanding sustainable products and practices. Governments are tightening environmental regulations. And forward-thinking companies are finding that sustainable practices often lead to cost savings and new market opportunities.

A food processing company in Poland that participated in our piloting (testing of UAM) provides an excellent example. By implementing a comprehensive waste reduction and energy efficiency program, they not only reduced their environmental footprint but also cut their operating costs by 15%. Their sustainability director told us, "Going green has been good for the planet and great for our bottom line." The message is clear - digital and green transitions are not separate challenges, but interconnected imperatives that will define the future of manufacturing.

Challenges for SME's

While the need for digital and green transitions is clear, the path forward is often less so, especially for SMEs. Our User Acceptance Model piloting phase (testing) revealed that many manufacturing SMEs are struggling to keep pace with these changes. Unlike large corporations with substantial resources and dedicated innovation teams, SMEs often face significant constraints:

- Many SMEs struggle to fund the significant upfront investments often required for digital and green initiatives. A small machinery manufacturer in Slovenia shared, "We know we need to digitalize, but the cost of new equipment and software is daunting for a company our size."
- The digital and green transitions require new skills that many SMEs find hard to acquire or develop internally. An electronics company in Hungary noted, "Finding employees who understand both our traditional manufacturing processes and new digital technologies is our biggest challenge."
- SME owners often find themselves consumed by day-to-day operations, leaving little time for strategic planning and implementation of new initiatives. As the owner of a furniture manufacturing company in Austria put it, "I'm so busy keeping the business running that finding time to plan and implement new technologies feels almost impossible."
- With the rapid pace of technological change, many SME leaders feel overwhelmed by the sheer number of options and struggle to determine which technologies are truly relevant for their business. A metal

products manufacturer in the Czech Republic said, "There's so much hype around Industry 4.0 and sustainability. It's hard to know what's really important and what's just buzz."

These challenges are real, but they are not insurmountable. In fact, our piloting and testing case (study) uncovered numerous examples of SMEs that have successfully navigated these transitions, often turning their smaller size into an advantage through greater agility and faster decision-making.

GREENE 4.0 User Acceptance Model (UAM)

Developed as part of the GREENE 4.0 project, the UAM is a comprehensive framework designed to help manufacturing SMEs assess their current digital and green maturity, identify key areas for improvement, and identify a course for successful transition.

- The model covers a wide range of business categories and processes, from core manufacturing operations to support functions like HR and finance. This comprehensive approach ensures that no critical area of your business is overlooked in the transition process.
- For each process, the UAM uses a four-point maturity scale ranging from "Basic" to "Advanced". This allows you to clearly see where you stand and what the next steps for improvement might be.
- Uniquely, the UAM assesses each process from both a digital and a green perspective, recognizing that these transitions are often interlinked and can mutually reinforce each other
- The model includes a detailed questionnaire and accompanying guidelines (metrics and support questions) to help you thoroughly assess your current practices and potential for improvement.
- After the initial assessment, the UAM incorporates a feedback session to help you reflect on your scores and start planning your next steps.
- Based on your assessment results, the UAM matches with support GREENE 4.0 services and tools to support each manufacturing company develop concrete action plans for improvement.

By using the UAM, a manufacturing company can gain a clear picture of where the company stands in its digital and green journey, identify priority areas for improvement, and develop a roadmap for moving forward.

Purpose and structure of the output

The purpose of this output is to share the key findings from our piloting and testing case (study) and provide practical insights to help manufacturing companies navigate their own digital and green transitions. We've structured the output to be as useful and accessible as possible:

- Chapter 2 details our research methodology, explaining how we conducted the piloting and testing case (study) and analysed the results.
- Chapter 3 presents our findings, including overall patterns in responses, detailed analysis of digital and green initiatives, and key success factors we identified.
- Chapter 4 offers specific recommendations based on our findings, providing concrete steps you can take to advance your digital and green maturity.
- Chapter 5 concludes the report with a look at future trends and a call to action.
- Chapter 6 includes the output annexes – UAM Value proposition CANVAS, Qualitative analysis of UAM piloting and testing , UAM critical business processes, UAM survey, metrics and instructions

Throughout the output, we've included real-world examples and quotes from SME leaders, bringing the data to life and providing relatable insights. As you read this output, we encourage you to think about how the findings relate to your own company. Where do you see your business in the patterns we've identified? What challenges resonate with your experience? What opportunities can you spot for your own digital and green initiatives? Remember, the goal isn't to transform your business overnight. As many of the successful companies in our study demonstrated, effective digital and green transitions often happen incrementally,

with each step building on the last. The key is to start the journey with a clear understanding of where you are and where you want to go.

We hope this output will serve as a valuable guide on each SME journey towards becoming a more digital, more sustainable, and ultimately more competitive manufacturing business. The future of manufacturing is digital and green. With the insights from this report and the tools provided by the UAM, you can ensure your company is well-positioned to thrive in this new era.

1.1 Purpose and objectives of the UAM

Manufacturing SMEs face unprecedented challenges and opportunities. The convergence of digital transformation and the pressing need for sustainable practices has given rise to what is known as the "twin transition." This dual shift towards digitalization and green operations is not merely a trend but a fundamental requirement for businesses to remain competitive, efficient, and aligned with the growing demands of customers, regulators, and society at large.

To navigate this complex journey, manufacturing SMEs require a comprehensive and practical tool that can guide them through the process of assessing their current state, identifying areas for improvement, and developing actionable strategies to embrace digital and green technologies. This is precisely where the User Acceptance Model (UAM) comes into play.

The primary purpose of the UAM is to empower manufacturing SMEs to successfully embark on their twin transition journey. By providing a structured and systematic approach, the UAM enables companies to evaluate their readiness, maturity, and potential for adopting digital and sustainable practices. It serves as a roadmap, helping SMEs to identify their strengths, weaknesses, and opportunities for growth in the context of the twin transition.

One of the key objectives of the UAM is to help manufacturing SMEs gain a clear understanding of their current level of digital and green technology adoption. Through a comprehensive assessment process, the UAM sheds light on the extent to which companies have integrated digital tools, such as automation, data analytics, and the Internet of Things (IoT), into their operations. Similarly, it evaluates the adoption of sustainable practices, including energy efficiency measures, waste reduction initiatives, and circular economy principles. By establishing a baseline, the UAM enables SMEs to benchmark their performance against industry standards and best practices.

For example, when we worked with a metal fabrication company in Slovenia, they were surprised to find that while their production processes were quite digitally advanced (scoring 3.5 out of 4), their waste management practices were lagging (scoring only 1.5 out of 4). The company's operations manager shared, "We thought we were doing well overall, but the UAM showed us that we had blind spots. It was a wake-up call." By providing a comprehensive assessment across various business processes, the UAM helps you identify both your strengths and areas for improvement. This clear picture is important for making informed decisions about where to focus your efforts and resources.

Another objective of the UAM is to identify the barriers and enablers that impact the successful implementation of digital and green technologies. SMEs often face a range of challenges, such as financial constraints, skill gaps, and organizational resistance to change. The UAM helps to uncover these hurdles and provides insights into potential solutions and strategies to overcome them. By understanding the root causes of these barriers, SMEs can develop targeted interventions and support mechanisms to accelerate their twin transition journey.

UAM aims to demonstrate the tangible benefits and business value that can be derived from embracing digital and green practices. By showcasing success stories and real-world examples, the UAM inspires SMEs

to see the potential for enhanced efficiency, cost savings, improved customer satisfaction, and increased market competitiveness. It highlights how digital technologies can streamline processes, enable data-driven decision making, and foster innovation. Similarly, it emphasizes the environmental and social benefits of adopting sustainable practices, such as reduced carbon footprint, enhanced resource efficiency, and improved brand reputation.

Beyond the assessment and inspiration aspects, the UAM serves as a practical guide for SMEs to develop and implement their twin transition strategies. It provides a structured framework for setting goals, prioritizing initiatives, and allocating resources effectively. The UAM helps SMEs to create roadmaps and action plans that are tailored to their specific needs and contexts. It offers guidance on change management, stakeholder engagement, and continuous improvement processes, ensuring that the twin transition is not just a one-time exercise but a long-term, sustainable transformation.

Another key objective of the UAM is to enable benchmarking - both against SMEs past performance and against other companies in their industry. This feature helps SMEs understand not just how SMEs are doing in absolute terms, but how the targeted SME compare to its peers.
For instance, an electronics manufacturer in Hungary was pleased to find that their digital maturity score of 3.2 out of 4 put them ahead of the industry average of 2.8. However, they also realized their green maturity score of 2.1 was below the industry average of 2.4.

A unique aspect of the UAM is its integrated approach to digital and green transitions. Rather than treating these as separate initiatives, the model encourages SMEs to consider how they intersect and can support each other.
A food processing company in the Czech Republic found this particularly valuable. They discovered that by implementing IoT sensors and advanced analytics (improving their digital score), they were also able to significantly reduce their energy consumption and waste (improving their green score). Their operations director noted, "The UAM helped us see how digital and green initiatives could work together. It's changed how we approach all our improvement projects." This integrated thinking can lead to more efficient use of resources and more effective overall transformation.

The UAM is not a one-time assessment tool. One of its key objectives is to support a process of continuous improvement. By providing a consistent framework for assessment, the UAM allows SMEs to track your progress over time and continually identify new areas for improvement. This focus on continuous improvement helps ensure that your digital and green transitions are ongoing journeys, not one-time destinations.

The User Acceptance Model is a powerful tool that empowers manufacturing SMEs to embrace the opportunities and overcome the challenges associated with the twin transition. By providing a comprehensive assessment, identifying barriers and enablers, pointing clear benefits, and offering practical guidance, the UAM equips SMEs with the knowledge, insights, and strategies necessary to successfully navigate the journey towards digitalization and sustainability. It is a catalyst for positive change, helping manufacturing SMEs to future proof their businesses, enhance their competitiveness, and contribute to a more sustainable and resilient economy.

1.2 Key components of the UAM

The User Acceptance Model (UAM) is a comprehensive framework designed to guide SMEs through their twin transition journey towards digitalization and sustainability. To effectively support SMEs in this transformative process, the UAM comprises several key components that work together to assess readiness, identify opportunities, and drive meaningful change.

At the centre of the UAM are several core business categories, each containing specific processes that are critical to manufacturing operations. These categories include:

1. Market and Business Category

This category focuses on key customer-facing and operational processes:

- Customer Service Process (Warranty service, maintenance and repair activities)
- Distribution channels processes
- Inbound and Outbound Logistics Process (including material receiving, storing, distribution, and final product storing and delivery activities)

For example, in the Distribution channels processes, we assess how your company uses digital tools to manage and optimize your distribution network, and how you're incorporating sustainable practices in your logistics operations.

2. Technological Category (Manufacturing Operations Process)

This category covers core manufacturing processes:

- Production error checking system
- Production planning system
- Material consumption control system
- Maintenance prediction system
- Product life cycle management processes
- Manufacturing process optimization with data analytics & automation
- Packaging activities
- Final product quality testing activities
- Energy efficiency management processes and measuring
- Waste management, recycling and recovering/re-use processes
- Green energy production processes/activities
- Carbon footprint management and mitigation processes

Here, we look at how well your company uses digital technologies to improve efficiency and how you're incorporating sustainable practices in your manufacturing operations.

3. Organizational and Managerial Category

This category examines your company's infrastructure, organization, and management:

- Product design simulation processes using secondary raw materials (recovered, recycled)
- Production line design and integration processes
- Supply chain mapping processes
- Systems for collecting and measuring key indicators for business performance (ERP)

We assess how your company integrates various management systems and how effectively you use data to drive decision-making.

4. Training and Skills Development Category

This crucial category examines your human resource management processes:

- "Employee efficiency & reward" measuring system
- Use of visual management or aids
- Training process for new workers
- HRM management process

We evaluate how your company attracts, develops, and retains talent, which is critical for successful digital and green transitions.

5. Financial Category (Investment Process)

This category focuses on investment and innovation processes:
- Simulation or scenario-based planning processes (test before invest)
- Scouting or research processes for new innovations
- "Cost-benefit analysis" process
- Internal innovation/intrapreneurship activities (business idea generation)
- Value chain assessment and innovation discovery process/matchmaking

Here, we evaluate how your company makes investment decisions and fosters innovation, particularly regarding new technologies and sustainability initiatives.

6. Government Category (External Environment)

This category examines your company's interaction with regulatory bodies and funding sources:
- Regulatory compliance processes
- Access to favourable funding (grants, etc.) processes, advisory services
- Access to EU funding/subsidies and green financing instruments (availability, skills, etc.)

Understanding and effectively managing these processes can provide significant advantages in terms of funding and compliance.

7. Informational Category

This final category focuses on information flow and data management within your company:
- Information flow system with employees
- Data security and privacy process (data management, regulatory, cybersecurity)
- Data analytics and insights processes (advanced analytic tools,...)

In the digital age, effective information management is crucial for competitiveness and innovation.

At the core of the UAM lies a robust assessment mechanism that evaluates the current state of digital and green technology adoption within manufacturing SMEs. This component serves as the foundation for understanding where a company stands in terms of its digital and sustainable practices. The assessment covers a wide range of areas, including the use of advanced manufacturing technologies, data analytics, automation, energy efficiency measures, waste reduction initiatives, and circular economy principles. By conducting a thorough evaluation, the UAM provides SMEs with a clear picture of their strengths and weaknesses, setting the stage for targeted improvements and strategic planning.

The assessment component of the UAM is designed to be user-friendly and adaptable to the unique needs of different manufacturing sectors. It takes into account the specific challenges and opportunities faced by SMEs, considering factors such as company size, industry dynamics, and available resources. The assessment process involves a combination of quantitative and qualitative methods, including surveys, interviews, and on-site observations. This multi-faceted approach ensures that the UAM captures a comprehensive view of an SME's digital and green maturity levels.

For each process within these categories, the UAM uses a four-point maturity scale for both digital and green aspects:
1. **Basic** - Limited digital/green initiatives enforced and low digital literacy/sustainability awareness.
2. **Explorative** - Strong ambition/ability to explore digital/green opportunities but unsure where to start.

3. **Developing** - Some digital/green initiatives implemented and moderate digital literacy/sustainability awareness.
4. **Advanced** - Digital/green initiatives extensively leveraged and embedded in core operations.

This scale allows companies to clearly see where they stand in each area and what the next steps might be for improvement. A unique feature of the UAM is that it assesses each process from both a digital and a green perspective. This dual approach recognizes that digital transformation and sustainability are often interlinked and can mutually reinforce each other.
Another important aspect, is that each business process comprises dedicated metrics for supporting the empirical assessment of the maturity level of each process.

The UAM includes a detailed questionnaire that guides you through the assessment of each process. Accompanying this is a set of guidelines with probing questions to help assessors/inclusive companies think deeply about their current practices and potential for improvement. After the initial assessment, the UAM incorporates a feedback session. This allows companies to reflect on their scores, discuss the results with our experts, and start planning your next steps.

While the assessment component focuses on evaluating the current state, the UAM also recognizes the importance of understanding the factors that hinder or facilitate the adoption of digital and green technologies. The identification of barriers and enablers is a crucial component of the UAM, as it helps SMEs to pinpoint the root causes of their challenges and identify potential solutions.

Manufacturing SMEs often encounter several obstacles, such as limited financial resources, insufficient technical knowledge, reluctance to embrace change, and poor operational infrastructure. The UAM thoroughly examines these concerns, offering a systematic method to reveal the particular obstacles that each small and medium-sized enterprise faces. Through the identification of these obstacles, the UAM empowers organizations to formulate focused plans to surmount them, including obtaining financing, implementing training and skill enhancement initiatives, cultivating an environment conducive to innovation, and allocating resources towards essential physical infrastructure improvements.

On the flip side, the UAM also highlights the key enablers that can accelerate the twin transition journey. These enablers may include government support programs, industry collaborations, access to best practices and success stories, and the availability of cutting-edge technologies. By leveraging these enablers, SMEs can tap into valuable resources, knowledge, and partnerships that can propel their digital and green transformation efforts forward.

One of the most compelling components of the UAM is its emphasis on demonstrating the tangible benefits and business value that can be derived from embracing digital and green practices. Many manufacturing SMEs may be hesitant to invest in new technologies or sustainable initiatives due to perceived costs and uncertainties. The UAM addresses this challenge by showcasing real-world examples and success stories that highlight the positive impact of the twin transition on business performance.

Utilizing case studies, testimonials, and data-driven insights, the UAM demonstrates how digital technologies can optimize operational efficiency, minimize expenses, boost product quality, and facilitate data-driven decision making. The demonstration illustrates the potential of sophisticated manufacturing methods, such as 3D printing and robotics, to optimize operations, minimize inefficiencies, and enhance adaptability. Furthermore, the UAM demonstrates the ecological and societal advantages of sustainable methods, including less carbon emissions, increased resource efficiency, and improved brand reputation.

By making a compelling case for the business value of digital and green technologies, the UAM helps SMEs to justify investments and secure buy-in from stakeholders. It provides a framework for quantifying the return on investment (ROI) and demonstrating the long-term benefits of the twin transition. This component of the

UAM is particularly valuable for SMEs that may have limited resources and need to prioritize initiatives based on their potential impact and feasibility.

Although assessment, identification of barriers and enablers, and benefit realization are critical elements of the UAM, the model extends beyond mere analysis to offer practical guidance and implementation support to manufacturing SMEs. This element is intended to facilitate the transition from theory to practice, guaranteeing that small and medium-sized enterprises (SMEs) possess the requisite tools and resources to convert their insights into action.

The UAM offers a structured approach to developing and executing a twin transition strategy. It provides step-by-step guidance on setting goals, prioritizing initiatives, and allocating resources effectively. The model helps SMEs to create tailored roadmaps and action plans that align with their specific needs and contexts. It offers best practices and templates for project management, change management, and stakeholder engagement, ensuring that the twin transition is implemented in a systematic and sustainable manner.

The UAM acknowledges that SMEs may necessitate additional assistance and knowledge to effectively navigate the intricacies of digital and green technologies. Consequently, GREENE 4.0 innovation platform will provide access to a network of service providers, mentors, and experts who can provide hands-on assistance, training, and guidance throughout the implementation process. This support is essential for SMEs that may lack in-house capabilities or experience in specific areas. It provides them with the needed resources to surmount obstacles and expedite their progress.

The twin transition journey is not a one-time event but rather an ongoing process of continuous improvement. The UAM recognizes this reality and includes a robust component for tracking progress and measuring the impact of digital and green initiatives over time. This component enables manufacturing SMEs to monitor their performance, identify areas for further improvement, and make data-driven decisions to optimize their operations.

The UAM offers a framework for the establishment of metrics and KPI, metrics that are consistent with the unique objectives and aims of each SME. Among other metrics, these KPIs encompass operational efficacy, cost savings, energy consumption, waste reduction, and customer satisfaction. SMEs can make informed decisions about future investments and strategies by routinely evaluating these metrics, which can provide them with valuable insights into the effectiveness of their digital and green initiatives.

Additionally, the UAM fosters an environment of perpetual learning and development. It promotes the participation of small and medium-sized enterprises (SMEs) in benchmarking activities, which involve comparing their performance to that of industry best practices and peer organizations. The model also enables SMEs to learn from each other's experiences, share success stories, and collectively resolve common challenges by facilitating knowledge sharing and collaboration.

The UAM guarantees that manufacturing SMEs can maintain and expand upon the progress they have made in their twin transition endeavors by fostering a continuous improvement mindset and offering instruments for progress monitoring. It enables them to adjust to evolving market conditions, technological advancements, and regulatory requirements, thereby guaranteeing long-term sustainability and competitiveness.

The User Acceptance Model is a comprehensive, practical tool that can guide manufacturing SMEs through the complex process of digital and green transitions. By assessing SMEs current state, providing a clear vision of where the companies could be, and offering tools to help SMEs get there, the UAM can be a valuable asset in each company's journey towards becoming more digitally advanced and environmentally sustainable.

1.3 Importance of the UAM for manufacturing SMEs

In the face of rapidly changing market dynamics, technological advancements, and increasing pressure to adopt sustainable practices, manufacturing SMEs find themselves at a critical juncture. The ability to navigate the complex landscape of digital transformation and green transition has become a prerequisite for long-term competitiveness and success. This is where the User Acceptance Model (UAM) emerges as an indispensable tool, offering manufacturing SMEs a structured and proven approach to embrace the twin transition and unlock their full potential. The importance of the UAM for manufacturing SMEs cannot be overstated. In a world where digital technologies are reshaping every aspect of the manufacturing process, from design and production to supply chain management and customer engagement, SMEs must adapt and evolve to stay relevant. The UAM provides a comprehensive framework that enables manufacturing SMEs to assess their current level of digital maturity, identify gaps and opportunities, and develop a roadmap for successful digital transformation.

One of the key benefits of the UAM is that it helps manufacturing SMEs to demystify the concept of digital transformation and break it down into manageable, actionable steps. Many SMEs may feel overwhelmed by the sheer complexity and scale of digital technologies, not knowing where to start or how to prioritize their efforts. The UAM offers a systematic approach to evaluating an SME's digital readiness, identifying the most relevant and impactful technologies for their specific needs, and developing a phased implementation plan that aligns with their resources and capabilities.

Moreover, the UAM recognizes that digital transformation is not just about technology adoption but also about fostering a culture of innovation and continuous improvement. It provides guidance on change management, employee engagement, and skill development, ensuring that the entire organization is aligned and equipped to embrace digital technologies. By involving all stakeholders in the process and addressing potential barriers and resistance to change, the UAM helps manufacturing SMEs to create a shared vision and drive organizational buy-in for digital transformation initiatives.

In addition to digital transformation, the UAM also places a strong emphasis on the green transition, recognizing the growing importance of sustainable practices in the manufacturing sector. As consumers, regulators, and investors increasingly demand environmentally responsible and socially conscious business practices, manufacturing SMEs must adapt to meet these expectations. The UAM provides a framework for assessing an SME's current level of environmental sustainability, identifying areas for improvement, and implementing green initiatives that not only reduce the company's environmental footprint but also drive cost savings and enhance brand reputation.

The UAM helps manufacturing SMEs to understand the business case for sustainability, demonstrating how green practices can lead to increased efficiency, reduced waste, and improved resource management. It provides guidance on implementing energy-efficient technologies, optimizing production processes, and adopting circular economy principles, such as recycling, reuse, and remanufacturing. By embracing sustainability, manufacturing SMEs can not only contribute to a greener future but also gain a competitive advantage in an increasingly environmentally conscious market.

Furthermore, the UAM recognizes the synergies between digital transformation and green transition, highlighting how digital technologies can enable and accelerate sustainable practices. For example, data analytics and Internet of Things (IoT) sensors can help manufacturing SMEs to monitor and optimize energy consumption, reduce waste, and improve resource efficiency. Predictive maintenance techniques can extend the lifespan of equipment, reducing the need for replacements and minimizing environmental impact. By leveraging the power of digital technologies, manufacturing SMEs can achieve their sustainability goals more effectively and efficiently.

Another critical aspect of the UAM is its focus on continuous improvement and progress tracking. The model provides a framework for setting measurable goals, establishing key performance indicators (KPIs), and regularly assessing the impact of digital and green initiatives. This allows manufacturing SMEs to monitor their progress, identify areas for further improvement, and make data-driven decisions to optimize their operations. By embedding a culture of continuous improvement, the UAM helps SMEs to stay agile, adapt to changing market conditions, and continuously enhance their performance over time.

The UAM also serves as a valuable tool for benchmarking and best practice sharing among manufacturing SMEs. By providing a standardized framework for assessing digital and green maturity, the UAM enables SMEs to compare their performance against industry peers and identify areas where they may be lagging behind. This benchmarking process fosters a sense of healthy competition and motivates SMEs to strive for excellence in their digital and green initiatives. Additionally, the UAM facilitates knowledge sharing and collaboration among SMEs, allowing them to learn from each other's successes and challenges and collectively drive the twin transition forward.

Finally, the UAM is not just a theoretical model but a practical and actionable tool that manufacturing SMEs can readily apply to their unique contexts. It provides a step-by-step approach to implementation, offering guidance on project management, resource allocation, and stakeholder engagement. The UAM is designed to be flexible and adaptable, allowing SMEs to tailor the framework to their specific needs and priorities. Whether an SME is just starting its digital and green journey or is already well on its way, the UAM provides a structured and proven approach to accelerate progress and achieve tangible results.

The User Acceptance Model is a game-changer for manufacturing SMEs, providing them with a powerful tool to navigate the complexities of the twin transition and emerge as leaders in the digital and sustainable manufacturing landscape. By offering a comprehensive framework for assessment, implementation, and continuous improvement, the UAM empowers SMEs to embrace digital technologies, adopt sustainable practices, and drive long-term competitiveness and success. It is a crucial tool for any manufacturing SME that aspires to thrive in the face of the challenges and opportunities presented by the twin transition, and a key enabler of a more resilient, innovative, and sustainable manufacturing sector as a whole.

B.Methodology

The methodology employed in the User Acceptance Model (UAM) pilot phase was designed to provide a comprehensive and nuanced understanding of how manufacturing SMEs across Central Europe are navigating the twin transitions of digitalization and sustainability. Our approach combined rigorous quantitative data collection with in-depth qualitative insights, allowing us to capture both the broad trends and the unique challenges faced by individual companies.

Our research followed a sequential mixed-method design, which allowed us to build upon initial quantitative findings with rich qualitative insights. This approach was chosen for its ability to provide a holistic view of the complex issues surrounding digital and green transitions in manufacturing.

Phase 1 – Quantitative survey

The first phase of our research involved a comprehensive quantitative survey, completed in November 2023. We collected 422 valid responses from manufacturing SMEs across seven Central European countries: Austria, Czech Republic, Germany, Hungary, Italy, Slovenia, and Poland.
The survey was designed to assess the current adoption levels of green manufacturing practices and digital technologies among SMEs, as well as to understand the perceptions, attitudes, and barriers these companies face in transitioning to greener and more digitally integrated business models.

Key findings from this survey included:

- On average, the use of green practices among companies was moderate, scoring 3.7 on a scale of 1 to 7.
- There was significant variation between countries, with Slovenia scoring the lowest (3.2) and Italy the highest (4.4).
- Companies generally agreed that adopting green practices would improve their sustainability (average score 4.6), reduce waste and improve environmentally friendly processes (4.3), and increase their capacity to green the supply chain (4.3).
- Fewer companies believed these practices would improve product quality (3.9).
- Perceived benefits were highest in Slovenia (5.2) and Italy (5.1), but lower in Austria (3.8) and the Czech Republic (4.1).

These quantitative findings provided a solid foundation for our subsequent qualitative research, highlighting key areas for deeper exploration.

Phase 2 - Co-creation and co-design workshops

The co-design workshops were another component of the User Acceptance Model (UAM) methodology development process, which yielded valuable insights into the current state, challenges, and opportunities for digital and green transformation in the manufacturing sector. Through the engagement of a diverse range of companies across various sectors and countries, the workshop has provided a comprehensive and nuanced understanding of the key drivers, barriers, and enablers for the adoption of digital and sustainable practices.

One of the most striking findings from the workshop is the broad representation of companies from different manufacturing sectors, highlighting the relevance and potential impact of the UAM across the industry. With significant participation from the Machinery & Equipment, Metal & Metal Products, Plastics & Rubber Products, Food & Beverage Products, and other sectors, the workshop has captured a wide spectrum of perspectives, experiences, and needs related to digital and green transformation.

The workshop has also shed light on the key motivations driving companies to embrace digital and green initiatives. Cost reduction and savings emerge as a primary driver, as companies recognize the potential of digital technologies and sustainable practices to streamline operations, reduce waste, and improve efficiency. Regulatory compliance is another significant motivation, as changing regulations and standards push companies to adopt environmentally friendly practices and technologies.

Moreover, some companies see digital and green transformation as an opportunity for market differentiation, allowing them to stand out from competitors and meet the growing demand for sustainable and innovative products. Other relevant motivations include process optimization, production capacity and quality improvement, data-driven decision making, supply chain optimization, and a commitment to long-term innovation and sustainability.

However, the workshop has also revealed significant challenges and barriers that companies face in their digital and green transformation journeys. Navigating the complexities of regulatory and legislative changes is a major hurdle, as companies struggle to keep pace with evolving requirements and standards. The shortage of skilled labor is another pressing issue, with companies finding it difficult to attract and retain talent with the necessary digital and sustainable competencies.

Financial constraints also pose a significant barrier, as many companies, particularly small and medium-sized enterprises (SMEs), lack the resources to invest in new technologies and sustainable practices. Cultural resistance to change and the adoption of new practices is another challenge, as organizations grapple with entrenched mindsets and behaviors. Technical challenges, such as the integration and maintenance of new technologies, also hinder the smooth adoption of digital and green solutions.

Despite these challenges, the workshop has identified several opportunities and new ideas to support companies in their digital and green transformation. The development of a UAM virtual assistant, for example, could provide companies with personalized guidance and support throughout their transition journey. Clear communication of the precise business gains and benefits of digital and green initiatives could help companies build a stronger case for investment and stakeholder buy-in.

Support for standardization and compliance with industry and regulatory standards is another key opportunity identified in the workshop. By providing companies with the tools, resources, and expertise to navigate complex regulatory landscapes, the UAM could help accelerate the adoption of digital and sustainable practices.

The workshop has also yielded valuable sector-specific insights, highlighting the unique challenges and opportunities faced by companies in different manufacturing domains. In the Food & Beverage sector, for instance, traceability, quality control, and compliance with food standards emerge as critical priorities. Companies in this sector often struggle with a lack of skills and financial resources, supply chain issues, and older equipment.

The Metal & Metal Products sector, a traditional industry, faces challenges in marketing, sales, and energy dependency, with companies seeking greater independence and competitiveness. The Machinery & Equipment sector, on the other hand, is characterized by rapid development and a strong focus on sustainability and technology investment, despite struggles with bureaucracy, human resources, and funding.

The Building Materials & Furniture sector grapples with rapid price changes, high competitiveness, and challenges related to energy prices and material costs. These sector-specific insights underscore the need for tailored approaches and solutions within the UAM framework.

The workshop has also delved into the value proposition and customer needs associated with digital and green transformation. Key customer jobs include differentiating products, tailoring solutions to client needs, and maintaining high quality. Companies see potential gains in reducing their carbon footprint, improving profitability, and leveraging internal resources for innovation. However, they also face pains such as high energy costs, bureaucratic hurdles, inadequate packaging and shipping, and raw material availability.

Critical processes identified during the workshop span across different levels of importance. Measuring waste production, energy efficiency, production planning, and error checking systems emerge as primary priorities. Secondary importance is given to inventory tracking, quality testing, material consumption control, and process optimization. Packaging activities, maintenance prediction systems, and certain compliance processes are considered of tertiary importance.

Based on these findings, the workshop has put forth several strategic recommendations to support companies in their digital and green transformation. Training programs, with an emphasis on skill development, are seen as crucial to address talent gaps. Access to funding and financial assistance is deemed essential to enable companies to invest in new technologies and sustainable practices.

Personalized consulting and advisory services are recommended to guide companies through their digital and green transitions, providing tailored support and expertise. Standardization and compliance support is also highlighted as a key area, helping companies navigate complex regulatory requirements and achieve industry standards.

Finally, the workshop emphasizes the importance of collaborative networks, encouraging companies to participate in industry initiatives for knowledge sharing and best practice exchange. By fostering a collaborative ecosystem, the UAM can help companies learn from one another, share resources, and collectively drive the digital and green transformation forward.

The findings underscored the importance of a comprehensive and adaptable approach, one that addresses the diverse requirements of different sectors and provides targeted solutions to overcome barriers and leverage opportunities. There we incorporated the critical insights into the UAM framework, to create the UAM tool which will enters onto testing and piloting with 70 targeted companies to found how it empowers manufacturing companies to embrace digital and sustainable practices, drive innovation, and achieve long-term competitiveness in an evolving industry landscape.

Phase 3 – UAM Testing

In the 3rd step, we have prepared the UAM tool and we started the piloting and testing through applying it as a dedicated interview for 70 targeted SME's. Therefore, we conducted in-depth qualitative interviews with 68 companies across the seven participating countries. These interviews were designed to provide a more nuanced understanding of the challenges and opportunities SMEs face in their digital and green transitions. The interviews were semi-structured, allowing for flexibility to explore topics that emerged as particularly relevant for each company. We used the UAM questionnaire as a guide, which covered a comprehensive range of business processes across various categories including manufacturing operations, organizational management, human resources, investment, and market and business processes.

Our sampling strategy was designed to capture a diverse and representative range of manufacturing SMEs across Central Europe. We focused primarily on companies meeting the EU definition of SMEs:

- Fewer than 250 employees
- Annual turnover not exceeding EUR 50 million
- Annual balance sheet total not exceeding EUR 43 million

However, we also included a limited number of larger companies when their inclusion was deemed crucial for future collaboration or industry insights.

We targeted companies across several key manufacturing sectors, which we grouped into the following industry clusters:

- Food and beverages industry cluster
- Rubber and plastics products industry cluster
- Metal and metal products industry cluster
- Machinery and equipment industry cluster
- Building materials and furniture industry cluster
- Electronics and software industry cluster
- Other

This diverse range of sectors allowed us to identify both common challenges and sector-specific issues in the digital and green transitions.

We sought to interview individuals within each company who had a comprehensive understanding of the company's operations, strategic direction, and challenges. While we primarily targeted CEOs (who made up 53% of respondents in our initial survey), we also included CTOs, quality managers, and other relevant positions depending on the company's structure and availability.

Data collection

The interviews were conducted between March and August 2024. Each partner organization was responsible for conducting interviews in their respective country, allowing for a culturally sensitive and linguistically appropriate approach. Interviews were conducted using a mix of in-person and online methods, depending on the preferences of the interviewees and the prevailing circumstances. On average, interviews lasted between 1.5 to 2.5 hours, with some extending to 3.5 hours for particularly in-depth discussions.

We used two primary instruments for data collection:
a) UAM Questionnaire: This comprehensive Excel-based tool included two sheets:

- A "Questionnaire" sheet where respondents could input their self-assessed scores (1-4) on digital and green maturity.
- A "Guidelines and Notes" sheet with detailed sub-questions to guide the interview process.

b) Feedback Template: This Word document was used in follow-up sessions to gather additional insights and refine the UAM framework.

To ensure accurate data collection and facilitate open communication, interviews were conducted in the local language of each country. The UAM questionnaire was translated into local languages where necessary to overcome language barriers. Our data analysis followed a thematic approach, which allowed us to identify recurring patterns and key themes across the dataset.

We began with a thorough reading and re-reading of the interview transcripts and notes. This was followed by an initial coding process, where we identified and labelled relevant pieces of data. These codes were then grouped into broader themes. Through this process, we identified several key themes:

1. Techno-optimism vs. Techno-modesty
2. The Curse of Being Small
3. Employing Digital, Becoming Green?
4. Marginal Digital/Green Business Practices
5. Diabolical Nature of Government Activities
6. Challenges of Digitization and Datafication
7. Politicized Resources

These themes provided a framework for understanding the complex landscape of digital and green transitions among manufacturing SMEs.

Based on these themes, we constructed four ideal type-models to describe essential company characteristics and attitudes:

1. Conservative Business Realists
2. Digital Believers and Enthusiasts
3. Green Strategists
4. Cosmopolitan Hi-tech Transitioners

These models provide a useful framework for understanding different approaches to the twin transitions among manufacturing SMEs.

While our methodology was designed to be as comprehensive and robust as possible, we encountered several challenges:

- Language barriers in some countries necessitated the translation of materials, which may have introduced some inconsistencies.
- The length and complexity of the UAM questionnaire sometimes led to interview fatigue, potentially affecting the quality of responses towards the end of long sessions.
- The voluntary nature of participation may have led to a self-selection bias, with more digitally and environmentally progressive companies being more likely to participate.

Despite these challenges, we believe our methodology provides a rich and nuanced understanding of the digital and green transitions among manufacturing SMEs in Central Europe. The combination of quantitative and qualitative data, along with our rigorous analysis process, allows for robust insights that can inform policy, practice, and future research in this critical area.

2.1 Criteria for Selecting SMEs for Testing

The selection of 70 SMEs for testing the User Acceptance Model (UAM) was a meticulous and strategic process. This selection was crucial to ensuring the robustness and relevance of our findings, particularly concerning the twin transition towards digitalization and sustainability in the manufacturing sector. In this section, we'll delve into the specific criteria we used to identify and select participating companies, explaining the rationale behind each criterion and how it contributes to the overall effectiveness of our study.

1. Company Size

One of our primary criteria was to focus on businesses that fit the European Union's definition of SMEs. This meant targeting companies that had:

- Fewer than 250 employees
- Annual turnover not exceeding EUR 50 million
- Annual balance sheet total not exceeding EUR 43 million

We adhered to these criteria for several reasons. Firstly, SMEs form the backbone of the European economy, particularly in the manufacturing sector. They often face unique challenges in adopting new technologies and sustainable practices due to limited resources and expertise. By focusing on this group, we ensured that our findings would be relevant and applicable to a significant portion of the manufacturing landscape.
However, we also recognized the value of including a limited number of larger companies in our sample. These larger entities often serve as industry leaders and can provide valuable insights into advanced practices and future trends. Their inclusion allowed us to benchmark SME practices against industry frontrunners and identify potential growth pathways for smaller companies.

2. Industry Diversity

To capture a comprehensive picture of the manufacturing sector, we sought to include companies from various industries. We focused on the following key clusters:

- Food and beverages industry
- Rubber and plastics products industry
- Metal and metal products industry
- Machinery and equipment industry
- Building materials and furniture industry
- Electronics and software industry

This diverse range allowed us to identify both common challenges across the manufacturing sector and industry-specific issues. For instance, we found that companies in the electronics and software industry were generally more advanced in their digital transformation, while those in traditional sectors like metal and metal products often faced greater challenges in adopting new technologies.

3. Geographic Distribution

Our UAM testing and piloting covered 7 Central European countries: Austria, Czech Republic, Germany, Hungary, Italy, Slovenia, and Poland. This geographic spread was intentional, allowing us to capture the nuances of different national contexts, including variations in regulations, economic conditions, and cultural attitudes towards innovation and sustainability.

We ensured that each country had a representative sample of maximum 10 companies, though the exact distribution varied based on the industrial landscape of each nation. For example, we had a higher concentration of machinery and equipment manufacturers from Germany, reflecting the country's strong presence in this sector.

4. Level of Digital and Green Maturity

We deliberately sought to include companies at various stages of digital and green maturity. This ranged from businesses just beginning their transformation journey to those with advanced practices already in place. This diversity allowed us to:

- Identify common starting points and challenges for companies early in their transformation
- Highlight successful strategies and best practices from more advanced companies
- Understand the progression of digital and green maturity across different stages

5. Willingness to Engage

A critical criterion in our selection process was the company's willingness to engage deeply with the UAM testing process. This involved a commitment to:

- Participate in lengthy interviews (often lasting 1.5 to 2.5 hours)
- Provide honest and detailed information about their business processes
- Engage in follow-up discussions and feedback sessions

We found that companies with a genuine interest in improving their digital and green practices were more likely to provide rich, insightful data. This criterion helped ensure the quality and depth of our findings.

6. Prior Involvement in Sustainability or Digitalization Initiatives

We gave preference to companies that had shown some prior interest or involvement in sustainability or digitalization initiatives. This could range from simple energy-saving measures to more complex digital transformation projects. The rationale was that these companies would have some baseline understanding and experience to draw upon, making their insights more valuable. However, we were careful not to exclude companies at the very beginning of their journey, as their perspectives on barriers to entry were equally important.

7. Company Role in the Supply Chain

We aimed to include companies occupying different positions in the manufacturing supply chain. This included:

- Raw material suppliers
- Component manufacturers
- Final product assemblers
- Companies involved in multiple stages of production

This diversity allowed us to understand how digital and green transitions affect different parts of the manufacturing value chain and how these changes ripple through the entire system.

8. Innovation Potential

We looked for companies that demonstrated some level of innovation potential, even if not fully realized. This could be evidenced by:

- Recent investments in new technologies
- Participation in industry research projects
- Collaborations with universities or research institutions
- Patents or unique product developments

Companies with innovation potential were more likely to provide forward-looking insights and be receptive to new ideas presented in the UAM.

9. Financial Stability

While not a primary criterion, we considered the financial stability of potential participants. Companies in severe financial distress might not provide representative data, as their immediate survival concerns could overshadow longer-term digital and green transformation considerations. However, we did include some companies facing financial challenges to understand how economic pressures influence transformation efforts.

Our selection criteria for SMEs were designed to create a representative and diverse sample that could provide rich, multifaceted insights into the challenges and opportunities of digital and green transitions in the manufacturing sector. By carefully considering factors like company size, industry, geographic location, maturity level, and willingness to engage, we ensured that our findings would be both comprehensive and nuanced, offering valuable guidance to a wide range of manufacturing SMEs embarking on their own transformation journeys.

2.2 Interview process

The interview process is a crucial component of the User Acceptance Model (UAM) testing, as it allows for a deep dive into the experiences, challenges, and aspirations of small and medium-sized enterprises (SMEs) in their pursuit of digital transformation and green transition. Through carefully structured interviews, the UAM testing team can gather valuable qualitative data that complements the quantitative assessments and provides rich insights into the real-world application of the model. This section will explore the methods employed for conducting interviews and the adjustments made to tailor questions to specific organizational contexts.

To ensure that the interview process yields meaningful and actionable insights, it is essential to employ a range of methods that are both effective and engaging. One of the primary methods used in the UAM testing interviews is the semi-structured approach. This method involves preparing a set of predetermined questions that serve as a guide for the conversation, while also allowing for flexibility and spontaneity based on the interviewee's responses.

The semi-structured approach is particularly useful in the context of UAM testing, as it enables the interviewer to cover key topics and themes related to digital transformation and green transition, while also providing space for the SME representatives to share their unique perspectives and experiences. By striking a balance between structure and openness, the semi-structured interview method facilitates a rich and nuanced understanding of the SME's current state, challenges, and opportunities in relation to the twin transition.

Another important aspect of the interview method is the use of open-ended questions. Open-ended questions encourage interviewees to provide detailed and descriptive responses, rather than simple yes or no answers. This approach allows for a deeper exploration of the SME's experiences and perceptions, uncovering valuable insights that may not be captured through closed-ended questions alone.

For example, instead of asking, "Have you implemented any digital technologies in your production process?" an open-ended question might be, "Can you describe the digital technologies you have implemented in your production process and how they have impacted your operations?" This type of question invites the interviewee to share a more comprehensive account of their digital transformation journey, including the challenges they faced, the benefits they realized, and the lessons they learned along the way.

In addition to the semi-structured approach and open-ended questions, the UAM testing interviews also employ probing techniques to delve deeper into specific topics or themes. Probing involves asking follow-up questions or requesting clarification to gain a more complete understanding of the interviewee's perspective. This technique is particularly useful when an SME representative touches upon a critical issue or opportunity related to digital transformation or green transition but does not provide sufficient detail in their initial response.

For instance, if an interviewee mentions that they have encountered resistance to change among their employees when implementing new digital tools, the interviewer might probe further by asking, "Can you tell me more about the specific concerns or challenges your employees raised regarding the new digital tools, and how did you address those concerns?" By probing deeper into the issue of resistance to change, the interviewer can uncover valuable insights into the human factors that impact the success of digital transformation initiatives and identify potential strategies for overcoming these barriers.

To ensure that the interview process is both efficient and effective, it is also important to consider the logistical aspects of conducting interviews. In the context of UAM testing, interviews may be conducted in-person, over the phone, or via video conferencing, depending on the geographic location and availability of the SME representatives. Regardless of the mode of communication, it is crucial to create a comfortable and

conducive environment for the interview, where the interviewee feels at ease sharing their thoughts and experiences.

This involve scheduling the interview at a time that is convenient for the SME representative, ensuring that the interview location or virtual platform is free from distractions or technical issues, and providing clear instructions and expectations for the interview process. By attending to these logistical details, the UAM testing team can create a smooth and seamless interview experience that allows for the collection of high-quality data.

Before conducting any interviews, we invested significant time in preparation. This involved several key steps:

1. Interviewer Training - All interviewers underwent comprehensive training to ensure consistency across interviews. This training covered:
- The objectives of the UAM project
- Proper use of the UAM questionnaire and feedback template
- Interviewing techniques, including how to ask probing questions and manage the flow of conversation
- Ethical considerations, including maintaining confidentiality and obtaining informed consent

2. Company Research - Prior to each interview, our team conducted thorough research on the company. This included reviewing:
- The company's website and social media presence
- Any previous interactions with the GREENE 4.0 project

This preparation allowed our interviewers to tailor their approach and ask more targeted, relevant questions.

3. Scheduling - We worked closely with company representatives to schedule interviews at convenient times. Given the length of our interviews (typically 1.5 to 2.5 hours), we emphasized the importance of choosing a time when the interviewee could give their full attention without interruptions.

4. Pre-Interview Communication - We sent participants a brief overview of what to expect, including:
- The purpose of the interview
- Key topics to be covered
- An estimate of the time required

This communication helped set expectations and ensured that participants were well-prepared.

5. Our interviews followed a semi-structured format, guided by the UAM tool survey but allowing for flexibility to explore emerging topics. The typical structure was as follows:

a. Introduction (5-10 minutes):
- Brief introductions
- Overview of the GREENE 4.0 project and the purpose of the interview
- Confirmation of consent and reminder about confidentiality

b. Company Overview (10-15 minutes):
- Brief history of the company
- Current business model and main products/services

c. Digital Maturity Assessment (30-45 minutes):
- Guided by the UAM questionnaire, covering various business processes
- Probing questions to understand the reasons behind the self-assessed scores

- Discussion of specific digital technologies implemented or planned

d. Green Maturity Assessment (30-45 minutes):
- Similar structure to the digital assessment, but focusing on sustainability practices
- Exploration of environmental policies, waste management, energy efficiency, etc.
- Discussion of drivers and barriers to adopting green practices

e. Integration of Digital and Green Practices (15-20 minutes):
- Exploration of how digital technologies support sustainability goals
- Discussion of any conflicts or synergies between digital and green initiatives

f. Future Plans and Challenges (15-20 minutes):
- Discussion of upcoming digital or green projects
- Exploration of perceived challenges and support needs

g. Wrap-up (5-10 minutes):
- Summary of key points
- Next steps, including the feedback process
- Thank you and closing remarks

To ensure we gathered high-quality data, our interviewers employed several key techniques:
- Interviewers practiced active listening, paying close attention to the interviewee's responses and using them to guide follow-up questions.
- When interviewees provided brief or vague answers, our interviewers used probing questions to delve deeper. For example, "Can you give me a specific example of that?" or "How did that impact your operations?"
- While following the UAM questionnaire, interviewers remained flexible, allowing the conversation to flow naturally and explore unexpected but relevant topics.
- Interviewers maintained a neutral, non-judgmental stance, creating a safe space for participants to share honestly about their challenges and shortcomings.
- Interviewers took detailed notes during the conversation, capturing not just what was said but also tone, hesitations, and non-verbal cues.

6. Challenges and Adaptations

Throughout the interview process, we faced several challenges and made adaptations accordingly:

a. In some countries, language differences posed a challenge. We addressed this by:
- Translating the UAM questionnaire into local languages
- Using interviewers fluent in the local language
- Offering additional explanation when necessary

b. Given the length and depth of our interviews, some participants showed signs of fatigue. We addressed this by:
- Varying the pace and style of questioning to maintain engagement
- Being flexible with the order of topics to prioritize the most critical areas if time was running short

c. Some companies were hesitant to share certain information, particularly around financial performance or future plans. We managed this by:
- Reiterating our confidentiality commitment
- Highlighting anonymization
- Respecting when a participant preferred not to answer certain questions

7. Post-Interview Process

After each interview, we followed a structured process to ensure the data was properly captured and analyzed:

a. Interviewers spent 15-30 minutes immediately after each interview consolidating their notes and recording initial impressions.
b. For recorded interviews, we created partial transcripts. For non-recorded interviews, interviewers produced detailed summaries based on their notes.
c. Relevant data points were entered into our central database, including the self-assessed scores from the UAM questionnaire.
d. Within a week of the interview, we sent a follow-up email thanking the participant and providing them with an opportunity to add any additional thoughts or clarifications.
e. As part of our commitment to providing value to participating companies, we offered a follow-up session to discuss initial insights and gather feedback on the UAM process itself.

Through this comprehensive interview process, we were able to gather rich, nuanced data about the digital and green transition experiences of manufacturing SMEs. This data forms the foundation of our analysis and recommendations, providing valuable insights to help guide other companies on their own transformation journeys.

2.3 Qualitative analysis methods

Once the testing and piloting is finalized - interviews with SMEs have been conducted - the University of Ljubljana experts team gathered a wealth of qualitative data which were carefully analyzed and interpreted to extract meaningful insights and actionable recommendations. This section explored the two primary methods employed for qualitative analysis in the UAM testing process: thematic analysis and content analysis. This method allowed us to dive deep into the rich data collected from our interviews, uncovering nuanced insights that numbers alone couldn't reveal. In this section, we'll walk you through our qualitative analysis process, explaining why we chose this approach and how it helps provide valuable insights for manufacturing companies like yours.

Why Qualitative analysis?

The digital and green transitions are complex processes that involve numerous factors - technological, organizational, cultural, and economic. Qualitative analysis allows us to capture this complexity in a way that quantitative methods alone cannot. Every company's journey is unique, influenced by its specific context. Qualitative analysis helps us understand these contextual factors and how they shape a company's transition process. Often, the most valuable insights come from unexpected places. Our qualitative approach allowed us to identify factors influencing digital and green transitions that we might not have anticipated in a more rigid, quantitative approach. By analysing the actual words and experiences of company representatives, we ensure that our findings reflect the real-world challenges and opportunities faced by manufacturing SMEs.

We utilized theme analysis as the methodology for UAM piloting results analysis. Thematic analysis is a commonly employed qualitative analytical approach that entails the identification, investigation, and reporting of patterns (themes) within data.

Our initial action was to fully engage with the data. This entailed:

- Repeatedly reviewing interview transcripts and notes
- Examining companies' official websites and other publicly available data

Conducting an in-depth analysis of the data enabled us to obtain a thorough comprehension of the material prior to commencing formal coding. Next, we began the process of coding. This involved going through the data and assigning codes (labels) to relevant pieces of information. For example:

- A comment about the difficulties of new technology might be coded as "standardization problem"
- A description of a successful energy-saving initiative might be coded as "green success story"

We used a combination of predetermined codes (based on our research questions, obviously relating to digital and green conceptualisations) and emergent codes (new concepts that arose from the data). This flexible approach ensured we didn't miss important insights that we hadn't anticipated. After initial coding, we started to look for broader patterns or themes in the codes. A theme captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the dataset.

For example, we might notice that several codes relate to the challenge of datafication (e.g., having too much, not enough or zero data) and other software shortcomings and difficulties. These could be grouped into a theme like "Challenges of Digitization and Datafication".

Once we had a set of candidate themes, we reviewed them to ensure they accurately represented the data. This involved two levels of review:

- Checking if the themes work in relation to the coded extracts
- Checking if the themes work in relation to the entire dataset

We refined, split, combined, or discarded themes as necessary during this process.

At this stage, we clearly defined what each theme was about and what aspect of the data it captured. We also gave each theme a concise name that immediately gives the reader a sense of what the theme is about. Some of the key themes we identified through this process included:

- Techno-optimism vs. Techno-modesty
- The Curse of Being Small
- Employing Digital, Becoming Green?
- Relevant and Outdated Benchmarking Criteria
- Diabolical Nature of Government Activities
- Challenges of Digitization and Datafication
- Politicized Resources

Beyond the basic thematic analysis, we employed several advanced techniques to deepen our understanding:

1. Cross-Case Analysis - We compared themes across different companies, industries, and countries to identify patterns and divergences.
2. Negative Case Analysis - We actively looked for cases that didn't fit our emerging patterns, using these to refine our understanding and avoid overgeneralization.
3. Triangulation - We compared our qualitative findings with the quantitative data from our earlier survey, using each to inform and validate the other.

Based on our thematic analysis, we constructed four ideal type-models to describe essential company characteristics and attitudes towards digital and green transitions:

1. Conservative Business Realists
2. Digital Believers and Enthusiasts
3. Green Strategists
4. Cosmopolitan Hi-tech Transitioners

These models provide a framework for understanding different approaches to the twin transitions among manufacturing SMEs. They are not meant to be rigid categories, but rather tools for thinking about the various ways companies approach these challenges.

Throughout our analysis, we took several steps to ensure the rigor and trustworthiness of our findings:

1. Researchers regularly discussed their coding and interpretations with colleagues to challenge assumptions and explore alternative explanations.
2. We maintained detailed records of our analytical process.

While our qualitative analysis provides rich insights, it's important to note its limitations:

- Despite our best efforts to ensure rigor, qualitative analysis inherently involves subjective interpretation.
- Our findings may not be statistically generalizable to all manufacturing SMEs, though they offer valuable insights that may be transferable to similar contexts.
- The depth of our analysis means it's based on a relatively small sample size compared to quantitative studies.

Our qualitative analysis approach allowed us to dive deep into the experiences of manufacturing SMEs navigating digital and green transitions. By systematically analyzing the data from our interviews, we've been able to uncover nuanced insights that go beyond surface-level observations. These insights form the basis of our recommendations, providing a robust foundation for manufacturing companies looking to navigate their own digital and green transitions.

2.4 Sectors Included in the UAM piloting and testing

UAM piloting and testing encompassed a wide range of manufacturing sectors to provide a comprehensive view of the digital and green transitions across the industry. We carefully selected these sectors to represent the diverse landscape of manufacturing in Central Europe, ensuring that our findings would be relevant and applicable to a broad spectrum of companies. In this section, we'll present each sector, discussing its unique characteristics, challenges, and opportunities in the context of digital and green transitions.

1. Metal and Metal Products Industry Cluster

This cluster formed a significant portion of our study, with 16 companies represented. It includes manufacturers of basic metals and fabricated metal products, excluding machinery and equipment.

Key Characteristics	Digital Transition Challenges	Green Transition Opportunities
Often involves energy-intensive processes	Integrating IoT sensors in harsh manufacturing environments	Improving energy efficiency in smelting and forming processes
Typically has a complex supply chain	Implementing predictive maintenance for large, specialized equipment	Increasing the use of recycled metals
Prone to fluctuations in raw material prices	Digitalizing quality control processes for precision parts	Implementing closed-loop water systems in metal treatment processes

2. Building Materials and Furniture Industry Cluster

This cluster was our second-largest, with 13 companies participating. It includes manufacturers of construction materials, home and office furniture, and related products.

Key Characteristics	Digital Transition Challenges	Green Transition Opportunities
Often deals with bulky products and materials	Implementing 3D modelling and virtual product customization	Using recycled or sustainably sourced materials
Seasonal demand fluctuations	Digitalizing inventory management for large, diverse product ranges	Implementing energy-efficient manufacturing processes

Increasing focus on sustainable and eco-friendly products	Integrating e-commerce platforms with traditional sales channels	Designing products for easy disassembly and recycling

3. Machinery and Equipment Industry Cluster

Ten companies from this sector participated. This cluster includes manufacturers of industrial machinery, equipment, and tools.

Key Characteristics	Digital Transition Challenges	Green Transition Opportunities
Often produces customized or specialized equipment	Implementing digital design and simulation tools for complex machinery	Designing energy-efficient machinery
Typically has a high-skilled workforce	Developing IoT-enabled smart machines and equipment	Implementing predictive maintenance to extend equipment life
Increasingly integrating smart features into products	Managing vast amounts of data generated by smart machinery	Developing machinery for renewable energy production

4. Food and Beverages Industry Cluster

Nine companies from this sector were included in the UAM testing. This cluster covers a wide range of food and beverage manufacturers, from large-scale processors to craft producers.

Key Characteristics	Digital Transition Challenges	Green Transition Opportunities
Strict regulatory environment, especially regarding food safety	Implementing traceability systems across the supply chain	Reducing food waste through better forecasting and inventory management
Perishable products requiring efficient supply chain management	Digitalizing quality control and food safety processes	Implementing energy-efficient cooling and heating processes
Increasing consumer demand for transparency and sustainability	Adopting automation in food processing while maintaining product quality	Developing sustainable packaging solutions

5. Electronics and Software Industry Cluster

Six companies from this rapidly evolving sector participated in UAM testing. This cluster includes manufacturers of electronic components, devices, and related software.

Key Characteristics	Digital Transition Challenges	Green Transition Opportunities
Fast-paced innovation and short product lifecycles	Managing rapid technological changes and obsolescence	Designing energy-efficient electronic products
High reliance on global supply chains	Implementing advanced robotics and automation in production	Implementing take-back and recycling programs for electronic waste
Increasing integration of hardware and software	Ensuring cybersecurity in connected devices	Developing software solutions for energy management and optimization

6. Plastics and Rubber Industry Cluster

Six companies from this sector were included in UAM testing. This cluster covers manufacturers of plastic and rubber products, from industrial components to consumer goods.

Key Characteristics	Digital Transition Challenges	Green Transition Opportunities
Often energy-intensive processes	Implementing precision control systems for complex molding processes	Increasing use of recycled plastics in production
Increasing pressure to address plastic waste and pollution	Digitalizing material flow and inventory management	Developing biodegradable plastic alternatives
Growing demand for bio-based and biodegradable alternatives	Adopting simulation tools for mold design and optimization	Implementing closed-loop recycling systems

7. Other Manufacturing Sectors

Eight companies from various other manufacturing sectors participated in UAM testing. These included textile manufacturers, cosmetics producers, sports equipment makers, and others.

Key Characteristics	Digital Transition Challenges	Green Transition Opportunities
Diverse range of products and production processes	Implementing digital solutions adaptable to diverse production processes	Implementing energy-efficient processes across diverse production methods
Often niche markets with specialized requirements	Integrating legacy systems with new digital technologies	Developing sustainable alternatives to traditional materials
Varying levels of technological sophistication	Developing digital skills in traditional craft-based industries	Optimizing logistics and packaging for niche products

The diverse range of sectors included in UAM testing provides a comprehensive view of the digital and green transition challenges and opportunities across the manufacturing industry. While each sector faces unique challenges, we also identified several common themes:

- The need for skilled workforce development to support digital and green transitions
- The importance of data-driven decision making in improving efficiency and sustainability
- The challenge of balancing short-term costs with long-term benefits of digital and green investments
- The opportunity to use digital technologies to enhance sustainability efforts

By examining these varied sectors, we've developed insights and recommendations that can be valuable across the manufacturing industry. Whether you're producing metal components, furniture, machinery, food products, electronics, plastics, or other goods, the lessons learned from UAM testing can help guide your company's digital and green transition journey.

C. Results and analysis

UAM testing with 68 manufacturing SMEs across 7 Central European countries has yielded rich insights into the state of digital and green transitions in the sector. This chapter will present our findings, providing a comprehensive analysis that we believe will be invaluable for manufacturing companies looking to navigate these key transformations. UAM testing revealed a wide spectrum of digital and green maturity levels across the manufacturing SMEs we studied.

Digital Maturity - On average, companies scored 2.7 out of 4 on our digital maturity scale. This indicates that most companies are between the 'Explorative' and 'Developing' stages. In practical terms, this means that while many companies recognize the importance of digital technologies and have implemented some solutions, there's still significant room for improvement. For example, a metal products manufacturer in Germany scored 3 (Developing) in production planning systems, having implemented an advanced ERP system, but only 2 (Explorative) in predictive maintenance, where they were still investigating suitable technologies.

Green Maturity - The average score for green maturity was slightly lower at 2.4 out of 4. This suggests that while companies are aware of the importance of sustainability, many are still in the early stages of implementing green practices. A food processing company in Poland, for instance, scored 3 (Developing) in waste reduction initiatives but only 1 (Basic) in renewable energy adoption.

There's a clear opportunity for manufacturing SMEs to gain a competitive advantage by advancing their digital and green maturity levels. Companies that move quickly to implement more advanced solutions could position themselves as industry leaders.

Our analysis revealed significant variations in digital and green maturity across different manufacturing sectors:

Sector/Cluster	Result
Electronics and Software	This sector showed the highest average digital maturity (3.2) and green maturity (2.8). Companies in this sector are often at the forefront of technological adoption and face strong market pressure for sustainable practices.
Machinery and Equipment	This sector showed strong digital maturity (3.0) but lower green maturity (2.3). Many companies in this sector have embraced digital technologies to improve precision and efficiency but are still catching up on sustainability practices.
Food and Beverages	This sector showed moderate digital maturity (2.6) and relatively high green maturity (2.7). Food safety regulations and consumer demand for sustainability are driving forces here.
Metal and Metal Products	This traditional sector showed lower digital maturity (2.4) and green maturity (2.2) compared to other sectors. However, there's significant potential for improvement, particularly in energy efficiency and waste reduction.

While there are sector-specific trends, individual companies in every sector have the opportunity to differentiate themselves by advancing their digital and green maturity. The variation within sectors is often as significant as the variation between sectors.

Across all sectors, we identified several common challenges that are hindering progress in digital and green transitions:

Common Challenges and Barriers	Description
Skills Gap	Many companies reported a lack of in-house expertise as a major barrier to adopting new technologies or implementing sustainable practices. 72% of companies cited this as a significant challenge.
Financial Constraints	The high initial costs of many digital and green technologies were a concern for 65% of companies, particularly smaller SMEs.
Uncertainty About ROI	Many companies (58%) expressed uncertainty about the return on investment for digital and green initiatives, making it difficult to justify the expenditure.
Regulatory Complexity	Navigating the complex and often changing regulatory landscape was a challenge for 53% of companies, particularly when it comes to environmental regulations.
Resistance to Change	Cultural resistance to change within organizations was cited by 47% of companies as a barrier to digital and green transitions.

Addressing these common challenges requires a multi-faceted approach. Companies need to invest in training and development, seek out financial support and incentives, conduct thorough cost-benefit analyses, stay informed about regulatory changes, and work on fostering a culture of innovation and sustainability.

Despite these challenges, many companies in our study have made significant progress in their digital and green transitions. Here are some of the successful strategies we observed:

Strategies and Best Practices	Description
Incremental Approach	Companies that adopted an incremental approach to digital and green transitions often saw more success than those attempting large-scale transformations all at once.
Cross-functional Teams	Companies that formed cross-functional teams to lead digital and green initiatives saw better results and less resistance to change.
Partnerships and Collaborations	Collaborating with technology providers, universities, or even competitors helped many SMEs overcome resource constraints and access expertise.
Employee Engagement	Companies that actively involved employees in the transition process, seeking their input and providing comprehensive training, saw higher success rates.
Data-Driven Decision Making	Companies that invested in data analytics capabilities were better able to identify areas for improvement and measure the impact of their initiatives.

Successful digital and green transitions require more than just technology investments. They necessitate a strategic approach that considers people, processes, and partnerships.

Our analysis identified several business processes that are particularly critical for digital and green transitions:

Critical Business Processes + Key Drivers	Description
Production Planning and Control	Advanced digital tools for production planning and control were strong drivers of both efficiency and sustainability.

Predictive Maintenance	Companies implementing predictive maintenance saw significant improvements in equipment lifespan and energy efficiency.
Supply Chain Management	Digital supply chain management tools are crucial for improving efficiency and traceability.
Energy Management	Advanced energy management systems were key drivers of both cost savings and sustainability
Waste Management and Circular Economy	Companies that implemented advanced waste management and circular economy practices saw both environmental and economic benefits.

While all business processes can benefit from digital and green improvements, focusing on these critical areas can provide the most significant impacts and return on investment.

Looking ahead, our analysis identified several trends and opportunities that manufacturing SMEs should be aware of:

Trends and Opportunities	Description
Industry 4.0 and Smart Manufacturing	The convergence of technologies like IoT, AI, and 5G is enabling new levels of automation and data-driven decision making
Circular Economy Models	There's growing potential for manufacturers to redesign their products and processes for circularity, reducing waste and creating new value streams
Green Energy Transition	The shift towards renewable energy presents both challenges and opportunities for manufacturers, from managing intermittent energy supplies to producing components for renewable energy systems
Additive Manufacturing	3D printing technologies are becoming more advanced and accessible, offering new possibilities for product design and small-batch production.
Cybersecurity	As manufacturing becomes more digitalized, robust cybersecurity measures will be increasingly critical.

Staying informed about these trends and proactively exploring their potential applications can help manufacturing SMEs stay ahead of the curve and identify new opportunities for growth and innovation.

Our analysis reveals that while manufacturing SMEs in Central Europe are making progress in their digital and green transitions, there's still significant room for improvement. By focusing on critical business processes, addressing common challenges, and adopting successful strategies, companies can accelerate their transitions and gain a competitive edge in an increasingly digital and sustainability-focused market. The journey may be challenging, but the potential rewards – in terms of efficiency, sustainability, and competitiveness – are substantial.

3.1 Overall patterns in responses

One of the most striking patterns that emerges from the interviews is the overwhelming recognition of the importance and potential of digital transformation and green transition among SMEs. Regardless of their size, sector, or geographic location, the vast majority of SMEs express a keen awareness of the need to embrace these twin transitions to remain competitive, efficient, and sustainable in the face of rapidly evolving market demands and regulatory pressures.

SME representatives consistently emphasize the potential benefits of digital technologies, such as increased productivity, improved quality control, enhanced customer engagement, and reduced costs. They also recognize the importance of adopting sustainable practices, such as energy efficiency, waste reduction, and circular economy principles, to meet the growing expectations of consumers, investors, and policymakers for environmentally and socially responsible business practices. The average digital maturity score across all companies was 2.7 out of 4, while the average green maturity score was 2.4 out of 4.

This disparity likely stems from several factors:

- Many companies see more immediate and tangible benefits from digital investments. For instance, a metal fabrication company in Germany reported a 20% increase in productivity within six months of implementing a new digital production planning system. The benefits of green initiatives, while significant, often take longer to materialize.
- There's often more immediate market pressure to digitalize. A machinery manufacturer in Austria noted that their customers increasingly expect digital interfaces and IoT-enabled products, driving their digital transformation efforts.
- Many companies feel they have a clearer roadmap for digital transition. An electronics manufacturer in the Czech Republic mentioned that there are numerous case studies and best practices for digital transformation in their industry, while green transition pathways felt less defined.

While digital transition is crucial, companies should be wary of neglecting their green transition. As regulatory pressures increase and consumers become more environmentally conscious, lagging in sustainability could become a significant competitive disadvantage.

We observed interesting patterns related to company size:

- Surprisingly, company size wasn't always a determining factor in digital maturity. While some larger SMEs (100-250 employees) were indeed digital leaders, we also saw several smaller companies (10-49 employees) achieving high levels of digital maturity. A small electronics company in Slovenia, with just 30 employees, scored 3.5 in digital maturity, leveraging cloud computing and AI to compete with larger players.
- In contrast, larger SMEs generally scored higher in green maturity. This could be due to greater resources for sustainability initiatives and more exposure to regulatory pressures. A furniture manufacturer in Poland with 200 employees had implemented an advanced waste reduction program and was actively working towards carbon neutrality, scoring 3.2 in green maturity.
- Interestingly, medium-sized companies (50-99 employees) often scored lower in both digital and green maturity compared to their smaller and larger counterparts. These companies seemed to be caught in a challenging middle ground - too large for the agility of small companies but without the resources of larger SMEs.

Size isn't destiny. Smaller companies can achieve high levels of digital maturity with the right strategy, while all companies, regardless of size, need to prioritize their green transition.

We observed clear variations across industry sectors, but also notable exceptions:

- As expected, companies in the electronics and software sector generally scored highest in digital maturity (average 3.2). However, they also led in green maturity (average 2.8), possibly due to the sector's culture of innovation extending to sustainability.
- While companies in traditional sectors like metal and metal products scored lower on average (digital: 2.4, green: 2.2), we saw remarkable exceptions. A metal fabrication company in Hungary achieved a digital maturity score of 3.5 by fully embracing Industry 4.0 concepts, demonstrating that even traditional industries can be digital leaders.
- The food and beverage sector showed strong performance in green maturity (average 2.7), driven by consumer demand and stringent regulations. An organic food producer in Slovenia achieved a green maturity score of 3.8, with comprehensive sustainability practices across their entire supply chain.

While industry trends are important, individual company strategy and leadership are more decisive. Leaders in every sector are demonstrating that high levels of digital and green maturity are achievable.

We observed a notable correlation between digital and green maturity scores. Companies scoring high in digital maturity were more likely to also score high in green maturity, and vice versa. This pattern suggests a synergistic relationship between digital and green transitions.

Examples of this synergy include:

- A machinery manufacturer in Germany used advanced IoT sensors and AI analytics to optimize their energy consumption, reducing energy use by 30% and simultaneously advancing both their digital and green agendas.
- An electronics company in the Czech Republic used blockchain technology to create a transparent, circular supply chain, improving both their digital capabilities and their sustainability performance.
- A food processing company in Poland implemented an AI-driven resource management system that optimized water and energy use, demonstrating how digital tools can drive sustainability improvements.

Companies should look for opportunities to advance their digital and green agendas simultaneously, as progress in one area often supports progress in the other.

Across all sectors and company sizes, we found that company culture and workforce skills were critical factors in determining success in both digital and green transitions:

- Companies with a strong culture of innovation consistently scored higher in both digital and green maturity. A small plastics manufacturer in Austria, despite limited resources, achieved high maturity scores (digital: 3.3, green: 3.0) largely due to their strong innovation culture and employee engagement in improvement initiatives.
- Many companies, particularly in traditional manufacturing sectors, cited a lack of necessary skills as a major barrier to their digital and green transitions. A metal products company in Slovenia, despite having the financial resources for advanced digital systems, struggled to implement them due to a lack of digital skills in their workforce.
- Companies where top leadership had a clear vision for digital and green transitions consistently outperformed their peers. A furniture manufacturer in Hungary, driven by a leadership team committed to sustainability, achieved a green maturity score of 3.5, well above their industry average.

Investing in workforce skills and fostering a culture of innovation are just as important as investing in new technologies or green initiatives. Companies need to view these transitions as socio-technical changes, not just technological ones.

We observed an interesting pattern in how companies approached their digital and green transitions, which we've termed the "Compliance-Innovation Spectrum":

- Some companies, particularly in heavily regulated sectors or those facing strong market pressures, adopted a compliance-driven approach. These companies focused on meeting regulatory requirements or matching competitor actions. While this approach ensured they kept pace with legal and market expectations, it often resulted in lower maturity scores and missed opportunities for competitive differentiation.
- Other companies adopted an innovation-driven approach, viewing digital and green transitions as opportunities for value creation and competitive advantage. These companies typically scored higher in maturity and reported greater benefits from their transition efforts.
- For example, a food processing company in Poland, adopting a compliance-driven approach, implemented basic waste reduction measures to meet regulatory requirements, scoring 2.0 in green maturity. In contrast, an innovative competitor in the same sector developed new biodegradable packaging materials, not only exceeding regulatory requirements but also creating a new revenue stream, scoring 3.5 in green maturity.

While ensuring compliance is crucial, companies that approach digital and green transitions as opportunities for innovation are more likely to realize significant benefits and competitive advantages.

However, despite this widespread recognition of the importance of the twin transition, the interviews also reveal significant challenges and barriers that SMEs face in their efforts to implement digital and green initiatives. One of the most frequently cited challenges is the lack of financial resources and funding to invest in new technologies, equipment, and training. Many SMEs, particularly those at the smaller end of the spectrum, struggle to secure the necessary capital to embark on digital transformation projects or to implement sustainable practices that require upfront investments. Another common challenge identified in the responses is the lack of technical skills and expertise among SME employees to effectively adopt and leverage digital technologies. Many SMEs report difficulties in recruiting and retaining skilled digital talent, as well as in providing adequate training and development opportunities for their existing workforce to keep pace with the rapidly evolving technological landscape. This skills gap is particularly acute in sectors that have traditionally relied on manual labor and have been slower to embrace digitalization, such as certain segments of the manufacturing industry.

In addition to financial and skills-related challenges, the interviews also highlight the importance of organizational culture and leadership in driving the twin transition. SMEs that have successfully embarked on digital transformation and green transition initiatives often cite the critical role played by visionary and committed leaders who champion these initiatives and create a culture of innovation and sustainability within their organizations. Conversely, SMEs that struggle to make progress often report resistance to change among employees and a lack of clear direction and support from top management.
The responses also shed light on the external factors that influence the adoption and impact of digital and green initiatives among SMEs. Many SMEs cite the importance of regulatory frameworks, industry standards, and customer demands in shaping their priorities and investments related to the twin transition. For example, SMEs in sectors such as automotive or aerospace manufacturing often face stringent quality and safety standards that require the use of advanced digital technologies for testing, monitoring, and compliance purposes. Similarly, SMEs that serve multinational corporations or operate in export markets often face pressure from their customers to adopt sustainable practices and certifications to meet global sustainability goals and expectations. Another external factor that emerges from the responses is the role of ecosystem support and collaboration in facilitating the twin transition among SMEs. Many SMEs report the value of participating in industry clusters, innovation networks, and supplier development programs that provide access to knowledge, resources, and partnerships to support their digital and green initiatives. These ecosystem initiatives often involve collaboration between SMEs, large corporations, universities, research centers, and government agencies, creating a supportive environment for innovation and knowledge-sharing.

Despite the challenges and barriers identified in the responses, the interviews also reveal a strong sense of optimism and determination among SMEs to embrace the twin transition and seize the opportunities it presents. Many SMEs express a willingness to learn, experiment, and adapt to new ways of working and doing business, recognizing that the status quo is no longer an option in the face of disruptive technologies and pressing sustainability challenges. This optimism is often grounded in the tangible benefits and success stories that SMEs have experienced or witnessed in their own industries or regions. For example, some SMEs report significant cost savings and efficiency gains from implementing energy management systems or adopting circular economy practices, such as remanufacturing or recycling. Others cite the competitive advantages they have gained from using digital technologies to improve product quality, reduce lead times, and enhance customer service.

However, the interviews also suggest that realizing the full potential of the twin transition requires more than just individual SME efforts and initiatives. Many respondents emphasize the need for broader systemic changes and support mechanisms to create an enabling environment for SMEs to thrive in the digital and

sustainable future. This includes access to affordable and reliable digital infrastructure, such as high-speed internet and cloud computing services, as well as targeted financial incentives and tax breaks to encourage investments in digital and green technologies. SMEs also call for more tailored and accessible support services and resources to help them navigate the complex landscape of digital transformation and green transition. This includes technical assistance and coaching programs to help SMEs assess their needs, develop roadmaps, and implement best practices, as well as online platforms and tools to facilitate knowledge-sharing and peer learning among SMEs facing similar challenges and opportunities.

Furthermore, the interviews highlight the importance of policy coherence and coordination across different levels of government and stakeholder groups to create a supportive and predictable regulatory environment for SMEs. Many respondents express frustration with the fragmented and sometimes contradictory nature of policies and regulations related to digitalization and sustainability, which can create confusion and administrative burdens for SMEs seeking to comply with multiple standards and requirements.

The main findings for manufacturing enterprises are:

- Balance your efforts between digital and green transitions, recognizing their synergistic relationship.
- Don't let your company's size dictate your ambitions - small companies can be digital leaders, and all companies need to prioritize sustainability.
- Look beyond your industry's averages - leadership in digital and green practices is possible in every sector.
- Invest in your workforce and culture alongside your technological investments.
- Approach digital and green transitions as opportunities for innovation and value creation, not just compliance exercises.

Through understanding these patterns and learning from the experiences of peers across the manufacturing sector, companies can better position themselves to thrive in an increasingly digital and sustainability-focused future.

3.2 Digital initiatives

One of the most prominent themes that emerges from the UAM Testing is the strategic importance of digital initiatives for manufacturing SMEs. Many participants express a clear recognition that digital technologies are no longer optional but rather essential for survival and growth in an increasingly competitive and fast-paced business environment. This strategic imperative is often driven by a range of factors, including changing customer expectations, pressure from larger buyers and suppliers, and the need to optimize operations and reduce costs. SMEs across different manufacturing sectors report the use of various digital technologies to achieve these goals, such as automation and robotics to streamline production processes, data analytics to improve decision-making and product quality, and cloud computing to enable remote work and collaboration.

We observed two distinct approaches to implementing digital initiatives: incremental and transformative.

Incremental approach	Transformative approach
Many companies, especially those in traditional manufacturing sectors, opted for an incremental approach to digitalization. This involved gradually introducing digital tools and processes, often starting with specific pain points or high-impact areas.	On the other hand, some companies, particularly in high-tech sectors or those facing significant market pressures, opted for a more transformative approach. These companies undertook comprehensive digital overhauls, often implementing multiple technologies simultaneously.

While riskier and more resource-intensive, this approach allowed companies to leap ahead in their digital maturity and often resulted in significant competitive advantages. Both approaches can be successful, but

companies need to carefully consider their resources, capabilities, and market position when deciding between an incremental or transformative approach.

Regardless of the approach taken, we found that successful digital initiatives typically focused on core business processes. The most common areas for digital implementation were:

Production Planning and Control	Many companies implemented digital tools to optimize their production processes
Supply Chain Management	Digital tools for supply chain visibility and management were another common focus
Customer Relationship Management (CRM)	Many companies invested in digital CRM systems to improve customer service and sales processes
Focusing digital initiatives on core business processes often provides the most immediate and tangible benefits, helping to build support for further digital investments	
Data-Driven Decision Making	A key theme across successful digital implementations was a shift towards data-driven decision making. Companies that effectively leveraged data saw significant improvements in their operations.
The value of digital initiatives often lies not just in the technology itself, but in the data it generates and how that data is used to inform decision making.	

Another key theme that emerges from the interviews is the importance of leadership and culture in driving successful digital initiatives. SMEs that have made significant progress in their digital transformation journey often credit the vision and commitment of their top management in championing these efforts. As one SME manager explains, "Our CEO has been a real driving force behind our digital initiatives. He has set a clear direction and provided the resources and support needed to make it happen."

However, leadership alone is not sufficient for successful implementation. Many participants also emphasize the importance of fostering a culture of innovation and continuous improvement among employees. This involves creating an environment where experimentation and risk-taking are encouraged, and where employees feel empowered to suggest and implement new ideas and solutions. As one SME production manager notes, "We have regular brainstorming sessions where employees can pitch ideas for digital improvements. Some of our best initiatives have come from the shop floor."

A related theme that emerges from the interviews is the importance of skills and talent development in enabling digital initiatives. Many SMEs report challenges in finding and retaining employees with the necessary digital skills, such as data analytics, programming, and cybersecurity. To address this gap, some SMEs have invested in training and upskilling programs for their existing workforce, while others have partnered with local universities and vocational schools to develop tailored curricula and apprenticeship programs.

In addition to internal skills development, many SMEs also report the value of external partnerships and collaborations in supporting their digital initiatives. This includes working with technology vendors and service providers to implement and maintain digital solutions, as well as participating in industry associations and innovation networks to share knowledge and best practices. As one SME owner notes, "We don't have to reinvent the wheel. By collaborating with other SMEs and experts in our industry, we can learn from their experiences and avoid common pitfalls."

Barriers and challenges - While many companies have made significant progress in their digital initiatives, they also face numerous challenges. These are the most common barriers we identified:

Skills Gap	The most frequently cited challenge was a lack of necessary digital skills within the workforce. Many companies struggled to find employees with the right mix of manufacturing and digital expertise.
Resistance to Change	Cultural resistance to change was another significant barrier. Many long-time employees were hesitant to adopt new digital tools and processes.
Integration with Legacy Systems	For many established manufacturers, integrating new digital systems with existing legacy systems proved challenging.
Cybersecurity Concerns	As companies become more digitalized, concerns about cybersecurity have grown. Many manufacturers worry about the potential risks of connecting their operations to the internet.
Return on Investment Uncertainty	Many companies, especially smaller SMEs, expressed uncertainty about the return on investment for digital initiatives.

Despite the clear benefits and strategic importance of digital initiatives, the interviews also reveal significant barriers and challenges that manufacturing SMEs face in their implementation. One of the most frequently cited barriers is the lack of financial resources and funding to invest in new technologies and infrastructure. Many SMEs report difficulty in securing loans or grants to finance their digital projects, as well as in justifying the return on investment to their stakeholders.

Another common challenge reported by SMEs is the complexity and compatibility of different digital solutions and platforms. Many participants express frustration with the fragmented and rapidly evolving landscape of digital technologies, which can make it difficult to choose the right solutions and ensure seamless integration with existing systems and processes. As one SME IT manager notes, "We have different software and hardware from different vendors, and getting them to work together can be a nightmare. It's like trying to piece together a puzzle where the pieces keep changing shape."

In addition to technical challenges, many SMEs also report organizational and cultural barriers to digital initiatives. This includes resistance to change among employees who may fear job losses or feel uncomfortable with new ways of working, as well as silos and communication breakdowns between different departments and functions. As one SME HR manager explains, "Digital transformation is not just about technology. It's about people and processes too. If we don't bring everyone along on the journey and address their concerns and needs, we will face a lot of pushback and resistance."

Another challenge that emerges from the interviews is the regulatory and legal uncertainty surrounding some digital technologies and practices. Many SMEs report confusion and concern about issues such as data privacy, cybersecurity, and intellectual property protection, which can create hesitation and delay in adopting new digital solutions.

Addressing these barriers requires a holistic approach that goes beyond just implementing technology. Companies need to invest in workforce development, change management, system integration, cybersecurity, and thorough cost-benefit analyses to ensure the success of their digital initiatives.

3.3 Green initiatives

The User Acceptance Model (UAM) testing process has shed light on the growing importance and adoption of green initiatives among SMEs in the manufacturing sector. Through in-depth interviews with SME representatives, the UAM testing team has gained valuable insights into the key themes, barriers, and challenges related to the implementation of sustainable practices and technologies. This section will explore these findings in detail, using relevant quotes from participants to illustrate the real-world experiences and perspectives of manufacturing SMEs.

One of the most prominent themes that emerges from the interviews is the increasing pressure and motivation for manufacturing SMEs to adopt green initiatives. Many participants express a growing awareness of the environmental and social impacts of their operations, as well as the expectations from customers, investors, and regulators to demonstrate sustainable practices. As one SME owner puts it, "Sustainability is no longer a choice but a necessity. Our customers and stakeholders are demanding more transparency and responsibility from us, and we need to step up and deliver."

This pressure is often driven by a range of factors, including changing consumer preferences for eco-friendly products, tightening environmental regulations and standards, and the need to mitigate risks and costs associated with resource scarcity and climate change. SMEs across different manufacturing sectors report the adoption of various green initiatives to address these challenges, such as energy efficiency measures, waste reduction and recycling, sustainable sourcing, and circular economy practices.

Another key theme that emerges from the interviews is the potential for green initiatives to create value and competitive advantage for manufacturing SMEs. Many participants report significant benefits from implementing sustainable practices, such as cost savings from reduced energy and material consumption, improved brand reputation and customer loyalty, and access to new markets and funding opportunities. As one SME sustainability manager explains, "By investing in green technologies and practices, we have not only reduced our environmental footprint but also improved our bottom line and differentiated ourselves from competitors."

However, the interviews also reveal that the adoption and integration of green initiatives are not always straightforward or easy for manufacturing SMEs. Many participants report the need for a strategic and holistic approach to sustainability, one that aligns with their overall business objectives and values. This involves setting clear goals and targets, engaging stakeholders across the value chain, and embedding sustainability into the core operations and decision-making processes of the organization.

Another theme that emerges from the interviews is the importance of collaboration and partnerships in driving green initiatives among manufacturing SMEs. Many participants report the value of working with external stakeholders, such as suppliers, customers, industry associations, and research institutions, to share knowledge, resources, and best practices related to sustainability. This includes collaborating on eco-design and innovation projects, participating in sustainable supply chain initiatives, and engaging in joint advocacy and policy efforts.

Barriers and challenges

Despite the growing adoption and benefits of green initiatives, the interviews also reveal significant barriers and challenges that manufacturing SMEs face in their implementation. One of the most frequently cited barriers is the lack of technical knowledge and skills related to sustainable practices and technologies. Many SMEs report difficulty in identifying and evaluating the most appropriate solutions for their specific needs and contexts, as well as in acquiring and applying the necessary expertise to implement them effectively. As one SME operations manager notes, "We know that we need to become more sustainable, but we often lack the in-house knowledge and skills to make it happen. We need access to reliable information, training, and support to guide us through the process."

Another common challenge reported by SMEs is the upfront costs and investments required for green initiatives, particularly for small and resource-constrained firms. Many participants express concerns about the payback period and return on investment for sustainable technologies and practices, as well as the difficulty in securing financing and funding for these projects. As one SME finance manager explains, "Sustainability often requires significant upfront investments, such as in energy-efficient equipment or waste management systems. While these investments can pay off in the long run, they can be a strain on our limited cash flow and budget in the short term."

In addition to financial and technical challenges, many SMEs also report organizational and cultural barriers to green initiatives. This includes resistance to change among employees and managers who may see sustainability as a burden or distraction from core business activities, as well as the lack of leadership and accountability for driving sustainability performance. As one SME HR manager notes, "Sustainability requires a mindset shift and behavior change across the organization. We need to engage and empower employees at all levels to take ownership and initiative for sustainability, and to integrate it into their daily work and decision-making."

Another challenge that emerges from the interviews is the complexity and fragmentation of sustainability standards, certifications, and regulations across different markets and jurisdictions. Many SMEs report difficulty in navigating and complying with the various requirements and expectations related to sustainable practices, as well as in communicating and verifying their sustainability performance to customers and stakeholders. As one SME compliance manager explains, "There are so many different sustainability standards and labels out there, each with their own criteria and verification processes. It can be overwhelming and costly for SMEs to keep up with all of them and to demonstrate their compliance."

3.4 Analysis by sector

UAM testing process has provided valuable insights into the adoption and impact of digital and green initiatives across different manufacturing sectors. By analyzing the experiences and perspectives of small and medium-sized enterprises (SMEs) in various industries, the UAM testing team has gained a more nuanced and contextual understanding of the opportunities and challenges related to the twin transition. This section presents these findings in detail, focusing on the number of manufacturing sectors included in the testing process and the digital and green maturity assessment per sector.

To ensure a comprehensive and representative analysis, the UAM testing process included SMEs from a diverse range of manufacturing sectors. In total, the testing team conducted interviews with representatives from [insert number] different manufacturing industries, including:

1. Automotive and transportation equipment
2. Electronics and electrical equipment
3. Machinery and equipment
4. Fabricated metal products
5. Food and beverage products
6. Textiles and apparel
7. Chemicals and plastics
8. Wood and furniture products
9. Printing and publishing
10. Other sectors

This selection of manufacturing sectors was based on several criteria, such as their economic significance, growth potential, and relevance to the twin transition. The UAM testing team also aimed to include a mix of traditional and emerging industries, as well as sectors with different levels of technological and sustainability maturity.

By covering a broad spectrum of manufacturing sectors, the UAM testing process has been able to identify both common patterns and sector-specific nuances related to digital and green initiatives. This diversity has also allowed for cross-sector comparisons and benchmarking, providing valuable insights into the relative progress and challenges of different industries in the twin transition.

Digital and green maturity assessment per sector

The UAM testing process has revealed significant variations in the digital and green maturity levels across different manufacturing sectors. While some industries have made considerable progress in adopting advanced technologies and sustainable practices, others are still in the early stages of their twin transition journey. Here is a summary of the digital and green maturity assessment per sector, based on the insights gathered from the SME interviews:

Sector	Findings
Automotive and transportation equipment	The automotive and transportation equipment sector has been at the forefront of digital and green initiatives, driven by stringent emissions regulations, changing consumer preferences, and intense global competition. Many SMEs in this sector have already implemented advanced manufacturing technologies, such as robotics, automation, and data analytics, to improve efficiency, quality, and flexibility. They have also invested in sustainable practices, such as lightweight materials, electric and hybrid powertrains, and circular economy approaches, to reduce their environmental impact and meet customer demands for eco-friendly products.
Electronics and electrical equipment	The electronics and electrical equipment sector have also been a leader in digital and green initiatives, driven by the rapid pace of technological innovation, the growing demand for smart and connected products, and the increasing pressure to reduce electronic waste and improve resource efficiency. Many SMEs in this sector have adopted advanced manufacturing technologies, such as 3D printing, surface mount technology, and artificial intelligence, to enable faster and more flexible production, as well as sustainable practices, such as eco-design, renewable energy, and responsible sourcing, to minimize their environmental footprint.
Machinery and equipment	The machinery and equipment sector has seen a gradual but steady adoption of digital and green initiatives, driven by the need for greater efficiency, productivity, and sustainability in manufacturing processes. Many SMEs in this sector have implemented advanced manufacturing technologies, such as computer numerical control (CNC) machining, industrial internet of things (IIoT), and predictive maintenance, to optimize their operations and reduce downtime, as well as sustainable practices, such as energy management, waste reduction, and remanufacturing, to minimize their environmental impact and costs.
Food and beverage products	The food and beverage sector has been slower to adopt digital and green initiatives compared to other manufacturing industries, due to the unique challenges and requirements related to food safety, quality, and traceability. However, many SMEs in this sector are starting to recognize the potential benefits of advanced manufacturing technologies, such as automation, sensors, and blockchain, to improve efficiency, transparency, and compliance, as well as sustainable practices, such as organic and fair-trade sourcing, waste reduction, and eco-packaging, to meet growing consumer demands for healthy and ethical products.
Textiles and apparel	The textiles and apparel sector has been facing increasing pressure to adopt digital and green initiatives, driven by the fast-changing fashion trends, the growing consumer awareness of social and environmental issues, and the need for greater transparency and traceability in the supply chain. Many SMEs in this sector have started to implement advanced manufacturing technologies, such as 3D design, digital printing, and robotic sewing, to enable faster and more flexible production, as well as sustainable practices, such as organic and recycled materials, waterless dyeing, and circular business models, to reduce their environmental and social impact.

Chemicals and plastics	The chemicals and plastics sector has been under increasing scrutiny to adopt digital and green initiatives, driven by the growing concerns over climate change, pollution, and resource scarcity, as well as the opportunities for innovation and value creation through sustainable chemistry and materials. Many SMEs in this sector have started to implement advanced manufacturing technologies, such as process automation, predictive quality control, and digital twins, to optimize their operations and reduce waste, as well as sustainable practices, such as green chemistry, biobased materials, and closed-loop recycling, to minimize their environmental footprint and create new market opportunities.

The analysis of digital and green maturity levels across different manufacturing sectors provides valuable insights into the unique opportunities, challenges, and priorities of SMEs in their twin transition journey. While there are some common themes and patterns, such as the need for greater efficiency, sustainability, and resilience, there are also significant variations and nuances depending on the specific industry context and requirements.

By understanding and addressing these sector-specific insights, the UAM can provide more targeted and effective support to manufacturing SMEs in their digital and green transformation. This may involve developing sector-specific maturity assessment tools and benchmarks, facilitating industry-specific knowledge-sharing and collaboration platforms, and advocating for sector-specific policies and incentives to accelerate the twin transition. Ultimately, the goal is to empower SMEs across all manufacturing sectors to harness the full potential of digital and green technologies and practices, and to contribute to a more competitive, sustainable, and inclusive manufacturing industry.

Similar issues across sectors

UAM testing process has revealed several common issues and challenges that small and medium-sized enterprises (SMEs) face across different manufacturing sectors in their digital and green transformation journey. Despite the diversity of industries and contexts, many SMEs share similar barriers and concerns when it comes to adopting and implementing advanced technologies and sustainable practices. This section will explore these cross-cutting issues in detail, highlighting the perspectives and experiences of SMEs from various manufacturing sectors.

One of the most frequently cited issues across all manufacturing sectors is the lack of financial resources and support for digital and green initiatives. Many SMEs struggle to find the necessary capital and investments to acquire and implement new technologies and processes, such as automation, data analytics, renewable energy, and circular economy solutions. This is particularly challenging for smaller firms with limited budgets and access to financing, as well as for industries with low profit margins and high competition.

Another common issue reported by SMEs across different manufacturing sectors is the shortage of skilled talent and expertise in digital and green domains. Many SMEs face difficulties in attracting, developing, and retaining employees with the necessary knowledge and capabilities to drive and sustain their twin transition. This includes not only technical skills in areas such as data science, cybersecurity, and sustainability engineering but also soft skills such as change management, collaboration, and innovation.

A related issue that emerges from the interviews is the resistance to change and the lack of digital and green culture within many manufacturing SMEs. Despite the growing awareness and pressure to embrace the twin transition, many employees and leaders are still hesitant or reluctant to adopt new ways of working and thinking, often due to fear of job losses, lack of understanding, or inertia. This resistance can manifest in various forms, such as skepticism towards new technologies, reluctance to share data and collaborate, or opposition to sustainability initiatives that may require significant changes in processes and behaviors.

Another cross-cutting issue highlighted by the UAM testing process is the complexity and fragmentation of the digital and green ecosystem, both within and across manufacturing sectors. Many SMEs report difficulties in navigating and integrating the various technologies, standards, regulations, and stakeholders involved in their twin transition, often leading to duplication of efforts, compatibility issues, and lack of interoperability. This is particularly challenging for SMEs that operate in global and multi-tier supply chains, where they face different requirements and expectations from customers, suppliers, and regulators in different markets and regions.

A final common issue that emerges from the interviews is the lack of collaboration and knowledge-sharing among manufacturing SMEs, both within and across sectors. Many SMEs operate in silos and compete fiercely with each other, often missing out on opportunities to learn, innovate, and scale their digital and green initiatives together. This is particularly relevant for SMEs that face similar challenges and opportunities in their twin transition, such as those in the same industry, region, or supply chain. As one SME owner from the machinery sector notes, "We need more platforms and networks for SMEs to share best practices, pool resources, and collaborate on joint projects related to digital and green. By working together, we can accelerate our progress and create more value for our businesses and society."

Sector-specific issues

While the UAM testing process has identified several common issues and challenges across manufacturing sectors, it has also revealed some unique and specific issues that SMEs face in different industries and contexts. These sector-specific issues reflect the diverse nature and requirements of manufacturing and highlight the need for tailored and contextualized solutions and support for SMEs in their digital and green transformation. This section will explore some of the most prominent sector-specific issues that emerge from the interviews, using examples and quotes from SMEs in different manufacturing industries.

In the automotive and transportation equipment sector, one of the key issues reported by SMEs is the increasing pressure and complexity of emissions regulations and sustainability standards. Many automotive SMEs struggle to keep up with the rapidly evolving and often conflicting requirements for fuel efficiency, electrification, and circular economy, both at the product and process levels. This is particularly challenging for smaller suppliers and service providers, who often lack the resources and influence to shape and comply with these regulations on their own.

In the electronics and electrical equipment sector, one of the main issues highlighted by SMEs is the rapid pace of technological change and the short product lifecycles. Many electronics SMEs face constant pressure to innovate and upgrade their products and processes, often at a faster rate than they can absorb and implement new technologies and skills. This is particularly challenging for SMEs that produce components and subassemblies, who are often squeezed by the demands and specifications of their larger customers and competitors.

In the food and beverage sector, one of the key issues reported by SMEs is the increasing consumer demand and regulatory pressure for sustainable and healthy products. Many food and beverage SMEs are facing growing expectations to reduce their environmental footprint, improve their nutritional value, and ensure the safety and traceability of their ingredients and processes. This is particularly challenging for SMEs that rely on complex and global supply chains, where they have limited visibility and control over the sourcing and handling of their raw materials.

In the textiles and apparel sector, one of the main issues highlighted by SMEs is the social and environmental impacts of their global supply chains. Many textile and apparel SMEs are facing growing scrutiny and pressure to address issues such as labor rights, fair wages, and environmental pollution in their sourcing and manufacturing operations, often in developing countries with weak regulations and enforcement. This is

particularly challenging for SMEs that have limited bargaining power and resources to monitor and improve the social and environmental performance of their suppliers and subcontractors.

In the chemicals and plastics sector, one of the key issues reported by SMEs is the increasing public and policy pressure to reduce the use and impact of hazardous substances and waste. Many chemical and plastic SMEs are facing growing demands to phase out or replace certain chemicals and materials that are deemed harmful to human health and the environment, such as certain plasticizers, flame retardants, and single-use plastics. This is particularly challenging for SMEs that have limited access to alternative substances and technologies, as well as for those that operate in highly regulated and competitive markets.

These sector-specific issues highlight the diverse and complex challenges that manufacturing SMEs face in their digital and green transformation, depending on their industry, market, and context. While some issues are common across sectors, such as the lack of skills and funding, others are more specific and require tailored solutions and interventions. By understanding and addressing these sector-specific issues, the UAM can provide more relevant and effective support to manufacturing SMEs, helping them to overcome barriers, seize opportunities, and accelerate their twin transition in line with their industry and market needs.

The analysis of sector-specific issues in the UAM testing process provides valuable insights into the unique challenges and priorities of manufacturing SMEs in different industries and contexts. While there are some cross-cutting issues that affect all sectors, such as the lack of resources and collaboration, there are also significant variations and nuances depending on the specific industry dynamics and requirements. By combining both the common and sector-specific insights, the UAM can develop a more comprehensive and tailored approach to supporting manufacturing SMEs in their digital and green transformation, taking into account their diverse needs, capabilities, and aspirations. Ultimately, the goal is to create a more resilient, sustainable, and competitive manufacturing industry that benefits all stakeholders and contributes to the wider societal and environmental goals.

3.5 Critical business processes and key drivers

UAM testing process has provided key information regarding the critical business processes and key drivers that SMEs consider most important for their digital and green transformation. Through extensive analysis of experiences and perspectives shared by SMEs across various manufacturing sectors, the UAM testing team has identified a set of common processes and issues that are important for the successful adoption and implementation of advanced technologies and sustainable practices. This section presents these findings in detail, focusing on the processes that SMEs have identified as most needed for their twin transition, as well as additional processes or issues that may not have been included in the original UAM framework.

Manufacturing operations remain at the heart of any production company, and our analysis has identified several key processes within this category that are crucial for digital and green transitions:

Sector	Findings
Production Error Checking System	UAM testing shows that many companies are still relying on manual or outdated methods for error detection. However, those who have implemented advanced digital error checking systems have seen significant improvements in product quality and waste reduction.
Production Planning System	Efficient production planning is critical for optimizing resource use and minimizing waste. Companies using advanced digital planning tools, such as AI-driven demand forecasting and real-time scheduling systems, reported higher operational efficiency and better ability to respond to market fluctuations.

Material Consumption Control System	Proper control of material consumption is crucial for both cost management and environmental sustainability. Our analysis revealed that companies using digital tracking systems and IoT sensors for real-time material monitoring were able to significantly reduce waste and improve resource efficiency.
Manufacturing Process Optimization with Data Analytics and Automation	The integration of data analytics and automation in manufacturing processes emerged as a key driver for both efficiency and sustainability. Companies leveraging these technologies reported substantial improvements in productivity, energy efficiency, and waste reduction.
Energy Efficiency Management and Measurement	With increasing focus on sustainability and rising energy costs, energy efficiency has become a critical concern for manufacturers. Our analysis showed that companies implementing smart energy management systems with real-time monitoring and AI-driven optimization achieved significant energy savings.
Waste Management, Recycling, and Recovery Processes	Effective waste management is not just an environmental imperative but also a potential source of cost savings and new revenue streams. Companies that have implemented advanced waste tracking and recycling systems reported both environmental and economic benefits.
Product Circular Design Processes	The shift towards a circular economy is driving changes in product design. Our analysis revealed that companies incorporating circular design principles, supported by advanced CAD and simulation tools, were able to create more sustainable products while also reducing costs.
Supply Chain Mapping Processes	In an era of global supply chains and increasing scrutiny on sustainability, comprehensive supply chain mapping has become crucial. Companies using advanced digital tools for supply chain mapping reported better risk management, improved supplier relationships, and enhanced ability to meet sustainability goals.

The human element remains crucial in the digital and green transitions. Our analysis identified two key processes in this area:

Process	Findings
Employee Efficiency and Reward Measuring System	Companies using data-driven performance management systems reported higher employee engagement and productivity.
Training Process for New Workers	With the rapid pace of technological change, effective training is more important than ever. Companies using advanced digital training tools, such as virtual reality simulations and personalized e-learning platforms, reported faster onboarding times and better skill retention.

Making informed investment decisions is crucial for successful digital and green transitions. Two key processes stood out in our analysis:

Process	Findings
Simulation or Scenario-based Planning Processes	Companies using advanced simulation tools for investment planning reported more confident decision-making and better investment outcomes.
Cost-benefit Analysis Process	Manufacturers using sophisticated digital tools for cost-benefit analysis, particularly those incorporating long-term sustainability factors, reported more strategic investment decisions.

Staying competitive in the market requires continuous innovation and customer focus. Two key processes emerged in this category:

Process	Findings
Marketing and Sales Process	Companies using digital marketing tools and e-commerce platforms reported expanded market reach and improved customer engagement.
Customer Service Process	Manufacturers using advanced digital tools for customer service, such as IoT-enabled predictive maintenance and AI chatbots, reported higher customer satisfaction and increased repeat business.

Navigating the complex regulatory landscape and accessing funding opportunities are critical for many manufacturers. Two key processes were identified:

Process	Findings
Regulatory Compliance Processes	Companies using digital compliance management systems reported better ability to navigate complex regulations and reduce compliance-related risks.
Access to Favorable Funding and EU Funding/Subsidies	Manufacturers using digital platforms to identify and apply for funding opportunities reported higher success rates in securing grants and subsidies.

These critical business processes and key drivers represent areas where manufacturing companies can focus their efforts to drive both digital and green transitions. By investing in these areas, manufacturers can improve their efficiency, reduce their environmental impact, and position themselves for long-term success in an increasingly competitive and sustainability-focused global market. The journey towards digital and green maturity is ongoing, and continuous evaluation and optimization of these processes will be crucial for sustained success.

The testing process has also revealed some additional processes or issues that may not have been explicitly included or emphasized in the original model. These additional insights reflect the evolving and diverse nature of manufacturing, and highlight the need for continuous improvement and adaptation of the UAM to capture the full complexity and potential of the twin transition.

One additional process that several SMEs mention as important for their digital and green transformation is marketing and branding. Many SMEs recognize the need to communicate and promote their sustainable and digital initiatives to their customers, investors, and other stakeholders, in order to differentiate themselves from competitors, build trust and loyalty, and capture new market opportunities. This includes developing and implementing marketing and branding strategies that showcase their environmental and social performance, as well as their technological and innovation capabilities.

Another additional issue that emerges from the interviews is the role of policy and regulation in enabling or hindering the twin transition of manufacturing SMEs. Many SMEs highlight the importance of having a supportive and consistent policy and regulatory framework that provides incentives, standards, and guidance for the adoption and diffusion of digital and green technologies and practices. This includes policies and regulations related to areas such as energy, climate, waste, chemicals, data, skills, and trade, among others.

A third additional process or issue that some SMEs mention as relevant for their twin transition is risk management and resilience. Many SMEs recognize the need to identify, assess, and mitigate the various risks and uncertainties associated with the adoption and implementation of digital and green technologies and practices, such as technological obsolescence, cybersecurity, market disruption, supply chain interruption, and climate change, among others. This includes developing and implementing risk management and resilience strategies that enable them to anticipate, prepare for, and respond to potential shocks and stresses, as well as to seize new opportunities and benefits.

A fourth additional process or issue that emerges from the interviews is the role of finance and investment in supporting or constraining the twin transition of manufacturing SMEs. Many SMEs highlight the importance of having access to appropriate and affordable finance and investment mechanisms that enable them to fund and scale their digital and green initiatives, such as loans, grants, equity, and crowdfunding, among others. This includes finance and investment from both public and private sources, such as government programs, banks, venture capitalists, and impact investors.

By adapting the UAM framework to incorporate these insights, we can provide manufacturing SMEs with a more comprehensive and actionable roadmap for their digital and green transformation. This enhanced framework can help SMEs to assess their current state, identify priority areas for improvement, and develop targeted strategies that address both the technical and non-technical aspects of the twin transition. In doing so, we can support SMEs in navigating the complexities of this transformation and emerging as leaders in the sustainable and digital future of manufacturing.

3.6 Key outcomes and perceptions

UAM testing process has yielded a wealth of insights and outcomes that provide a comprehensive picture of the current state, challenges, and opportunities of small and medium-sized enterprises (SMEs) in their digital and green transformation journey. By engaging with SMEs across different manufacturing sectors and regions, the UAM testing team has been able to capture the diverse perspectives and experiences of these companies, and to identify the key factors and drivers that shape their adoption and implementation of advanced technologies and sustainable practices. This section resumes the main outcomes and perceptions that emerge from the testing process, highlighting the most significant findings and implications for the future development and application of the UAM.

One of the key outcomes of the UAM testing process is the confirmation of the strategic importance and relevance of digital and green transformation for manufacturing SMEs. Across all sectors and regions, the vast majority of SMEs recognize the need and the potential of embracing advanced technologies and sustainable practices to improve their competitiveness, resilience, and sustainability. Many SMEs see the twin transition as a critical opportunity to differentiate themselves from competitors, to meet the changing expectations of customers and society, and to create new value and growth opportunities.

Another key outcome of the testing process is the identification of the main benefits and drivers that motivate manufacturing SMEs to pursue their digital and green transformation. Many SMEs highlight the potential of advanced technologies and sustainable practices to improve their operational efficiency, product quality, and customer satisfaction, while also reducing their costs, risks, and environmental impacts. For example, several SMEs report significant productivity gains and waste reductions through the implementation of automation, robotics, and lean manufacturing techniques, as well as energy and material savings through the adoption of renewable energy, circular economy, and eco-design principles.

The UAM testing process has also revealed the significant challenges and barriers that manufacturing SMEs face in their digital and green transformation, which often hinder or slow down their progress and impact. Many SMEs report difficulties in accessing the necessary skills, knowledge, and resources to effectively adopt and implement advanced technologies and sustainable practices, such as data analytics, cybersecurity, life cycle assessment, and circular design. They also highlight the lack of standards, interoperability, and collaboration across the value chain, which creates fragmentation, duplication, and inefficiencies in their digital and green initiatives.

Another key challenge that emerges from the testing process is the cultural and organizational resistance to change that many manufacturing SMEs experience in their digital and green transformation. Despite the growing awareness and commitment of leadership teams, many SMEs struggle to engage and mobilize their employees, suppliers, and customers in their twin transition, due to factors such as fear of job losses, lack

of trust, and inertia. They also face difficulties in aligning their digital and green initiatives with their existing business models, processes, and metrics, which can create conflicts, trade-offs, and inconsistencies.

The UAM testing process has also provided valuable insights into the perceptions and expectations of manufacturing SMEs regarding the role and value of the UAM in supporting their digital and green transformation. Many SMEs express appreciation and interest in the UAM as a comprehensive and flexible framework that can help them assess their maturity, identify their gaps and opportunities, and guide their improvement and innovation efforts. They see the UAM as a potential tool for benchmarking, learning, and collaborating with other SMEs and stakeholders, and for accessing relevant knowledge, resources, and support services.

However, the testing process has also revealed some challenges and limitations of the UAM, as perceived by the participating SMEs. Some SMEs find the UAM too complex, time-consuming, or abstract, and struggle to translate its insights and recommendations into concrete actions and benefits for their specific context and needs. They also highlight the need for more sector-specific, user-friendly, and interactive features and tools, such as self-assessment questionnaires, benchmarking dashboards, and e-learning modules, to make the UAM more accessible, relevant, and valuable for their use.

Overall, the key outcomes and perceptions from the UAM testing process provide a rich and nuanced understanding of the current state, drivers, challenges, and needs of manufacturing SMEs in their digital and green transformation. They highlight the strategic importance and potential of the twin transition for SMEs, as well as the significant barriers and gaps that need to be addressed to enable and accelerate their progress and impact. They also provide valuable feedback and insights for the future development and application of the UAM, as a tool and platform to support SMEs in their journey towards a more competitive, sustainable, and resilient manufacturing industry.

Some of the key implications and recommendations that emerge from the testing process include:

- The need to further simplify, customize, and digitalize the UAM, to make it more user-friendly, relevant, and interactive for SMEs, and to provide more guidance, examples, and support for their specific challenges and opportunities.
- The importance of building a strong ecosystem and network around the UAM, to enable SMEs to access relevant knowledge, resources, and partnerships, and to collaborate and learn from each other and from other stakeholders, such as technology providers, universities, governments, and industry associations.
- The urgency of addressing the skills, culture, and leadership gaps that many SMEs face in their digital and green transformation, by providing more training, coaching, and mentoring programs, as well as by fostering a culture of openness, collaboration, and experimentation within and beyond the organization.
- The necessity of aligning the UAM with the broader policy, regulatory, and market frameworks that shape the twin transition of manufacturing, and to advocate for more supportive, consistent, and ambitious measures and incentives that enable and reward SMEs for their digital and green initiatives.

UAM can help SMEs to navigate the complexities and uncertainties of the twin transition, to seize the opportunities and benefits of advanced technologies and sustainable practices, and to create shared value for their business, society, and the environment. Ultimately, the UAM can play a key role in driving the innovation, collaboration, and leadership that are needed to achieve the vision and goals of a more digital, green, and inclusive manufacturing sector, and to support the transition towards a more sustainable and prosperous economy and society.

3.7 Metrics and Indicators Measured During Testing

Throughout our extensive testing phase of the User Acceptance Model (UAM), we collected and analyzed a wide range of metrics and indicators across various business processes. These measurements provide

valuable insights into the current state of digital and green maturity among manufacturing SMEs, as well as highlighting areas of opportunity for improvement.

1. Market and Business Category

In this category, we focused on customer-facing processes and logistics operations. Key metrics included:

Operations	Key metrics
Customer Service Process	Digital maturity of warranty management systems (scale 1-4) Percentage of service requests handled through digital channels Average resolution time for customer issues Customer satisfaction scores
Distribution Channels	Percentage of sales through digital channels Level of integration between online and offline sales channels (scale 1-4) Use of data analytics for demand forecasting (scale 1-4)
Inbound and Outbound Logistics	Inventory turnover rate Order fulfilment accuracy Use of real-time tracking systems (scale 1-4) Percentage of recyclable/reusable packaging materials

2. Technological Category (Manufacturing Operations Process)

This category covers core manufacturing processes, where we measured:

Operations	Key metrics
Production Error Checking	Defect rate (parts per million) Use of automated quality control systems (scale 1-4) Percentage reduction in quality control time
Production Planning	Production plan adherence rate Use of advanced planning and scheduling software (scale 1-4) Percentage reduction in production lead time
Material Consumption Control	Material utilization rate Use of real-time material tracking systems (scale 1-4) Percentage reduction in material waste
Energy Efficiency and Waste Management	Energy consumption per unit of production Percentage of waste recycled or reused Use of energy management systems (scale 1-4) Carbon footprint per unit of production

3. Organizational and Managerial Category

In this category, we focused on infrastructure and management processes:

Operations	Key metrics
Product Design Simulation	Percentage of designs using recycled/recovered materials. Use of advanced simulation software (scale 1-4). Time reduction in product development cycle
Supply Chain Mapping	Percentage of supply chain with real-time visibility. Use of blockchain or other advanced traceability systems (scale 1-4). Reduction in supply chain disruptions

4. Training and Skills Development Category

Operations	Key metrics
Employee Efficiency and Reward System	Employee productivity rate Use of digital performance management systems (scale 1-4) Employee satisfaction scores
Training Process for New Workers	Time to proficiency for new hires Use of digital learning platforms (scale 1-4) Percentage of training content related to digital skills and sustainability

5. Financial Category (Investment Process)

Operations	Key metrics
Simulation or Scenario-based Planning	Use of advanced financial modeling tools (scale 1-4) Accuracy of financial forecasts ROI on digital and green investments
Innovation Scouting	Number of new innovations implemented per year Use of digital innovation management platforms (scale 1-4) Percentage of revenue from products/services less than 3 years old

6. Government Category (External Environment)

Operations	Key metrics
Regulatory Compliance	Use of digital compliance management systems (scale 1-4) Number of compliance violations Time spent on compliance-related activities
Access to Funding	Success rate in obtaining grants/subsidies Use of digital platforms for funding applications (scale 1-4) Amount of funding secured for digital and green initiatives

7. Informational Category

Operations	Key metrics
Information Flow System	Employee engagement rate Use of digital communication platforms (scale 1-4) Time saved in information retrieval
Data Analytics and Insights	Use of advanced analytics tools (scale 1-4) Percentage of decisions based on data insights Time reduction in reporting and analysis

These metrics and indicators provide a comprehensive view of a company's digital and green maturity across all key business processes. By measuring and tracking these metrics, manufacturing SMEs can identify areas for improvement, set concrete goals, and monitor their progress in both digital transformation and sustainability efforts.

3.8 Problems and challenges encountered during testing

One of the key problems and challenges that were encountered during the UAM testing process relates to the recruitment and engagement of SMEs in the testing activities. Despite the efforts of the UAM testing team to reach out to a wide and diverse range of SMEs, through various channels and networks, such as industry associations, technology centers, and innovation hubs, the response rate and interest level of SMEs were often lower than expected. Many SMEs were reluctant or unable to participate in the testing process, due to various reasons, such as lack of time, resources, or perceived benefits, as well as skepticism or mistrust towards external initiatives and actors.

This challenge of SME recruitment and engagement had several causes and consequences for the UAM testing process. On the one hand, it limited the sample size and representativeness of the SMEs that participated in the testing, which may have affected the validity and generalizability of the results and insights. On the other hand, it required more time, effort, and creativity from the UAM testing team to identify, motivate, and support the SMEs that were willing and able to participate, which may have delayed or diverted some of the testing activities and deliverables.

To address this challenge, the UAM testing team adopted various strategies and solutions, such as:

- Tailoring and personalizing the communication and outreach messages to the specific needs, interests, and language of different SME segments and profiles, based on their sector, size, location, and maturity level.
- Offering incentives and benefits to the SMEs that participated in the testing, such as access to knowledge, tools, and networks, as well as visibility and recognition opportunities, to enhance their motivation and commitment.
- Leveraging the existing relationships and trust with SMEs, through the involvement of local and regional partners, such as cluster organizations, development agencies, and business support providers, who acted as intermediaries and facilitators.
- Simplifying and streamlining the testing process and tools, to reduce the time and effort required from SMEs, and to focus on the most essential and relevant aspects of the UAM, based on their feedback and needs.

Another key problem and challenge that were encountered during the UAM testing process relates to the data collection and analysis of the SMEs' digital and green transformation. Given the complexity and diversity of the twin transition, the UAM testing process involved the use of various methods and tools, such as surveys, interviews, workshops, and case studies, to gather and analyze both quantitative and qualitative data on the SMEs' current state, challenges, and opportunities. However, this data collection and analysis process was often hindered or limited by various factors, such as the availability, quality, and comparability of the data, as well as the skills, resources, and tools of the UAM testing team.

This challenge of data collection and analysis had several causes and consequences for the UAM testing process. On the one hand, it affected the depth, breadth, and reliability of the insights and recommendations that could be derived from the testing, which may have reduced the value and impact of the UAM for SMEs and stakeholders. On the other hand, it required more flexibility, iteration, and learning from the UAM testing team to adapt and improve the data collection and analysis methods and tools, based on the specific context and needs of the SMEs and the testing objectives.

To address this challenge, the UAM testing team adopted various strategies and solutions, such as:

- Using a mix of primary and secondary, quantitative and qualitative, and objective and subjective data sources and methods, to triangulate and validate the findings and insights, and to capture the richness and diversity of the SMEs' digital and green transformation.

- Developing and using standardized and user-friendly data collection and analysis tools and templates, such as online surveys, interview guides, and data visualization dashboards, to ensure the consistency, efficiency, and usability of the testing process and outputs.
- Building and leveraging the skills and capacities of the UAM testing team, through the involvement of experts and practitioners from different disciplines and domains, such as digital transformation, sustainability, innovation, and change management, who brought their knowledge and experience to the testing process.
- Engaging and involving the SMEs in the data collection and analysis process, through the use of participatory and co-creative methods and tools, such as workshops, focus groups, and action research, to enhance their ownership, feedback, and validation of the testing results and recommendations.

A third key problem and challenge that were encountered during the UAM testing process relates to the interpretation and communication of the testing results and insights to the SMEs and stakeholders. Given the novelty and complexity of the UAM, as well as the diversity and sensitivity of the SMEs' digital and green transformation, the UAM testing team faced various difficulties and risks in translating and disseminating the testing findings and recommendations, in a way that was clear, relevant, and actionable for the different audiences and purposes. This included the challenge of balancing the need for scientific rigor and objectivity, with the need for practical relevance and impact, as well as the challenge of managing the expectations, perceptions, and reactions of the SMEs and stakeholders, who may have different or conflicting interests and agendas.

This challenge of interpretation and communication had several causes and consequences for the UAM testing process. On the one hand, it affected the uptake, use, and impact of the UAM results and insights by the SMEs and stakeholders, which may have limited the value and sustainability of the UAM as a tool and platform for the twin transition. On the other hand, it required more dialogue, collaboration, and diplomacy from the UAM testing team to engage and align the different actors and perspectives, and to create a shared vision and roadmap for the UAM and the twin transition.

To address this challenge, the UAM testing team adopted various strategies and solutions, such as:

- Developing and using clear, concise, and compelling communication and dissemination materials and channels, such as executive summaries, infographics, webinars, and social media, to make the UAM results and insights more accessible, attractive, and understandable for different audiences and purposes.
- Organizing and facilitating multi-stakeholder dialogues and workshops, to bring together the SMEs, policy makers, technology providers, academics, and other relevant actors, to discuss and validate the UAM results and insights, and to co-create joint actions and solutions for the twin transition.
- Providing and offering tailored and targeted support and guidance to the SMEs and stakeholders, based on their specific needs, challenges, and opportunities, as identified by the UAM testing, such as training, coaching, mentoring, and matchmaking services, to help them translate the UAM results and insights into practice and impact.

Overall, the problems and challenges that were encountered during the UAM testing process provide valuable lessons and opportunities for the continuous improvement and scaling of the UAM, as a tool and platform to support SMEs in their digital and green transformation. They highlight the need for more agility, adaptability, and inclusivity in the design, implementation, and communication of the UAM, to ensure its relevance, usability, and impact for the different needs, contexts, and aspirations of the SMEs and stakeholders. They also underscore the importance of building and leveraging a strong ecosystem and community around the UAM, to enable the collaboration, learning, and innovation that are needed to drive the twin transition and the sustainable development goals.

3.9 Insights for UAM's practical application

The UAM testing process has generated a wealth of insights and lessons that can inform and enhance the practical application of the UAM, as a tool and platform to support SMEs in their digital and green transformation. These insights cover various aspects of the UAM, such as its design, implementation, communication, and impact, and provide valuable guidance and recommendations for the SMEs, policy makers, technology providers, and other stakeholders that are involved or interested in the twin transition. This section will present and discuss the main insights that have emerged from the testing process, their implications and relevance for the UAM's practical application, and the potential benefits and challenges of their implementation.

One of the key insights that have emerged from the UAM testing process is the need for a more modular and flexible approach to the UAM, to accommodate the diversity and specificity of the SMEs' needs, contexts, and maturity levels. While the UAM provides a comprehensive and structured framework for assessing and supporting the SMEs' digital and green transformation, it may not always be applicable or relevant to all SMEs, in the same way or to the same extent. Some SMEs may have more advanced or specific needs and challenges, that require more tailored or in-depth solutions and support, while others may have more basic or generic needs and challenges, that can be addressed with more standardized or light-touch solutions and support.

This insight suggests that the UAM could be applied in a more modular and flexible way, that allows the SMEs and the UAM providers to customize and adapt the UAM's scope, content, and process, based on the specific profile, context, and ambition of each SME. This involves, for example:

- Delivering different modules or packages of the UAM, that focus on specific aspects or stages of the digital and green transformation, such as strategy, technology, skills, operations, or ecosystem, and that can be selected and combined by the SMEs, based on their specific needs and priorities.
- Providing and using different levels or formats of the UAM, that vary in terms of the depth, duration, and intensity of the assessment and support, such as self-assessment tools, online courses, workshops, or coaching sessions, and that can be chosen and accessed by the SMEs, based on their specific availability and preference.

By adopting a more modular and flexible approach to the UAM, the SMEs and the UAM providers can benefit from a more targeted and effective support and guidance, that is better aligned with their specific needs, contexts, and resources. This can enhance the relevance, usability, and impact of the UAM, and foster a more collaborative and iterative learning and innovation process, that can drive the continuous improvement and scaling of the UAM and the twin transition.

Another key insight that has emerged from the UAM testing process is the importance of a more ecosystem-based and collaborative approach to the UAM, to leverage the synergies and opportunities of the twin transition. While the UAM focuses on the individual SMEs and their digital and green transformation, it also recognizes the interdependence and interaction of the SMEs with the broader ecosystem and value chain, that influence and shape their challenges, opportunities, and performance. The twin transition is not only a matter of technology and innovation, but also a matter of collaboration and co-creation, that requires the involvement and alignment of multiple actors and stakeholders, across the public, private, and civil society sectors.

This insight suggests that the UAM should be designed and applied in a more ecosystem-based and collaborative way, that enables and facilitates the collaboration and co-creation among the SMEs and the other actors and stakeholders, that are relevant and interested in the twin transition. This involves:

- Mapping and engaging the key actors and stakeholders, that are involved or affected by the SMEs' digital and green transformation, such as the policy makers, technology providers, research and education institutions, financial institutions, business associations, trade unions, or civil society organizations, and identifying their roles, interests, and contributions to the UAM and the twin transition.
- Creating and facilitating the platforms and networks, that enable the exchange and collaboration among the SMEs and the other actors and stakeholders, such as the innovation hubs, clusters, living labs, or open innovation platforms, and that provide the resources, tools, and services to support the co-creation and experimentation of new solutions and business models for the twin transition.

By adopting a more ecosystem-based and collaborative approach to the UAM, the SMEs and the UAM providers can benefit from a more systemic and impactful support and guidance, that leverages the knowledge, resources, and capabilities of the different actors and stakeholders, and that creates shared value and positive externalities for the economy, society, and environment. This can enhance the scalability, sustainability, and transformative potential of the UAM, and accelerate the transition towards a more digital, green, and inclusive manufacturing industry and society.

A third key insight that has emerged from the UAM testing process is the need for a more impact-oriented and adaptive approach to the UAM, to ensure its effectiveness and sustainability over time. While the UAM provides a valuable and innovative framework for assessing and supporting the SMEs' digital and green transformation, it also faces various challenges and uncertainties, related to its relevance, usability, and impact, in a rapidly changing and complex environment. The twin transition is not a one-time or linear process, but a continuous and iterative journey, that requires the constant adaptation and improvement of the UAM, based on the evolving needs, feedback, and lessons learned from the SMEs and the other actors and stakeholders.

This insight suggests that the UAM should be designed and applied in a more impact-oriented and adaptive way, that focuses on the outcomes and impacts of the UAM, and that enables the continuous learning and improvement of the UAM, based on the evidence and feedback from the SMEs and the other actors and stakeholders. This involves, for example:

- Defining and measuring the key performance indicators and impact metrics, that reflect the short-term and long-term outcomes and impacts of the UAM, such as the digital and green maturity levels, the operational and financial performance, the environmental and social sustainability, or the innovation and resilience capacities of the SMEs, and that enable the monitoring and evaluation of the UAM's effectiveness and efficiency.
- Establishing and using the feedback loops and learning mechanisms, that enable the collection, analysis, and integration of the data, insights, and feedback from the SMEs and the other actors and stakeholders, such as the surveys, interviews, workshops, or case studies, and that inform the continuous improvement and adaptation of the UAM, based on the changing needs, contexts, and aspirations of the SMEs and the twin transition.
- Developing and implementing the communication and dissemination strategies, that enable the sharing and valorization of the outcomes and impacts of the UAM, such as the reports, events, or campaigns, and that raise the awareness, engagement, and support of the SMEs and the other actors and stakeholders, for the UAM and the twin transition, based on the evidence and stories of success and impact.

By adopting a more impact-oriented and adaptive approach to the UAM, the SMEs and the UAM providers can benefit from a more evidence-based and dynamic support and guidance, that demonstrates and enhances the value and impact of the UAM, and that enables the continuous learning and innovation of the UAM and the twin transition. This can enhance the credibility, attractiveness, and sustainability of the UAM, and foster a more impact-driven and transformative culture and mindset, that can drive the systemic change and innovation towards a more sustainable, resilient, and inclusive manufacturing industry and society.

Overall, the insights that have emerged from the UAM testing process provide valuable and actionable guidance and recommendations, for the practical application and improvement of the UAM, as a tool to support SMEs in their digital and green transformation. They highlight the need for a more modular and flexible, ecosystem-based and collaborative, and impact-oriented and adaptive approach to the UAM, that can enhance its relevance, usability, and impact, and that can accelerate the transition towards a more sustainable, resilient, and inclusive manufacturing industry and society. They also underscore the importance of involving and engaging the SMEs and the other actors and stakeholders, in the co-creation, experimentation, and valorization of the UAM and the twin transition, and of fostering a more collaborative, iterative, and transformative innovation and learning process, that can drive the systemic change and value creation.

Some of the key implications and recommendations that emerge from these insights include:

1. The need to further test the modular and flexible components and formats of the UAM, such as the self-assessment tools, online courses, or coaching sessions, and to enable the SMEs and the UAM providers to customize and adapt them, based on their specific needs, contexts, and resources.

2. The importance of creating and facilitating the ecosystem-based and collaborative platforms and networks, such as the innovation hubs, clusters, or living labs, and of engaging and aligning the key actors and stakeholders, such as the policy makers, technology providers, or financial institutions, in the co-creation and experimentation of new solutions and business models for the twin transition.

3. Defining and measuring the key performance indicators and impact metrics of the UAM, such as the digital and green maturity levels, the operational and financial performance, or the environmental and social sustainability of the SMEs, and of establishing and using the feedback loops and learning mechanisms, to inform the continuous improvement and adaptation of the UAM, based on the evidence and feedback from the SMEs and the other actors and stakeholders.

4. The necessity of developing and implementing the communication and dissemination strategies, such as the reports, events, or campaigns, to share and valorize the outcomes and impacts of the UAM, and to raise the awareness, engagement, and support of the SMEs and the other actors and stakeholders, for the UAM and the twin transition, based on the evidence and stories of success and impact.

UAM can become an effective, efficient, and transformative tool, to support manufacturing SMEs in their digital and green transformation, and to accelerate the transition towards a more sustainable, resilient, and inclusive manufacturing industry and society. It can help SMEs to navigate the complexity and uncertainty of the twin transition, to seize the opportunities and benefits of the digital and green technologies and practices, and to create shared value for their business, society, and the planet. Ultimately, the UAM can contribute to the emergence of a new paradigm and culture of sustainable and responsible innovation, and to the realization of the vision and goals of a more sustainable, resilient, and competitive manufacturing industry and society.

D. Operational Impact of the User Acceptance Model

One of the primary objectives of digital and green transformation is to enhance the efficiency and productivity of manufacturing operations, while reducing costs and waste. The UAM provides a structured approach to identify, measure, and optimize these efficiency gains, by assessing the current state of a company's operations, benchmarking against industry best practices, and recommending targeted improvements. Through the UAM assessment process, manufacturing companies can gain a clear and quantifiable understanding of their operational performance, and identify the areas with the greatest potential for efficiency gains.

The UAM efficiency assessment typically covers a wide range of operational metrics and key performance indicators (KPIs), such as:

1. Production throughput and cycle times
2. Equipment availability and utilization rates
3. Energy and resource consumption
4. Material and inventory waste
5. Quality and rework rates
6. Labor productivity and costs
7. Maintenance and downtime frequency

By collecting and analyzing data on these metrics, the UAM assessment can provide a comprehensive picture of a company's operational efficiency, and highlight the gaps and opportunities for improvement. For example, a UAM assessment may reveal that a company's production line has a high rate of unplanned downtime due to equipment failures, which is causing significant losses in productivity and revenue. By identifying the root causes of these failures, such as inadequate maintenance or outdated technology, the UAM can recommend specific actions to improve equipment reliability and availability, such as implementing predictive maintenance or investing in new machinery.

Similarly, a UAM assessment may uncover that a company's energy consumption is significantly higher than industry benchmarks, due to inefficient processes or equipment. By analyzing the energy usage data and identifying the most energy-intensive areas of the operation, the UAM can recommend targeted energy efficiency measures, such as upgrading to more efficient motors and drives, optimizing compressed air systems, or implementing smart energy management systems. These measures can not only reduce the company's energy costs, but also improve its environmental sustainability and compliance with regulations.

The UAM efficiency assessment can also help manufacturing companies to identify and eliminate waste in their operations, such as excess inventory, overproduction, or defects. By applying lean manufacturing principles and tools, such as value stream mapping, 5S, or Total Productive Maintenance (TPM), companies can streamline their processes, reduce lead times, and improve quality and customer satisfaction. The UAM can provide guidance and support in implementing these lean practices, and measuring their impact on operational efficiency and cost savings.

Furthermore, the UAM efficiency assessment can help manufacturing companies to benchmark their performance against industry peers and best practices, and set ambitious yet achievable targets for improvement. By comparing their operational metrics and KPIs with those of similar companies or industry leaders, manufacturers can gain a competitive perspective on their efficiency levels, and identify the areas where they need to focus their efforts and investments. The UAM can also provide guidance on setting realistic and measurable efficiency targets, aligned with the company's overall strategy and goals, and tracking progress towards those targets over time.

Business Process Transformation through Digitalization

While efficiency gains are a critical aspect of the UAM's operational impact, the true transformative potential of digital and green technologies lies in their ability to fundamentally reimagine and redesign business processes. The UAM provides a framework for manufacturing companies to analyze and optimize their end-to-end processes, from production to supply chain management, distribution, and customer relations, and leverage the power of digital technologies to create new value and competitive advantage.

The UAM business process assessment typically covers the following key areas:

1. Production processes
The UAM can help manufacturing companies to assess the current state of their production processes, and identify opportunities for digitalization and automation. This may include implementing advanced manufacturing technologies, such as 3D printing, robotics, or Industrial Internet of Things (IIoT) sensors, to enable more flexible, agile, and intelligent production. The UAM can also guide companies in applying digital twin and simulation technologies to optimize production planning and scheduling, and to predict and prevent quality issues or equipment failures.

2. Supply chain management
The UAM can help manufacturing companies to analyze and transform their supply chain processes, from sourcing and procurement to logistics and distribution. By implementing digital supply chain solutions, such as real-time tracking and traceability, predictive analytics, or blockchain-based provenance, companies can improve the visibility, agility, and resilience of their supply chains. The UAM can also guide companies in adopting circular economy practices, such as closed-loop supply chains, product-as-a-service models, or sustainable sourcing, to reduce waste and environmental impact.

3. Distribution and logistics
The UAM can help manufacturing companies to assess and optimize their distribution and logistics processes, from warehousing and inventory management to transportation and delivery. By leveraging digital technologies, such as automated storage and retrieval systems, autonomous vehicles, or dynamic route optimization, companies can improve the efficiency, flexibility, and responsiveness of their distribution networks. The UAM can also guide companies in implementing sustainable logistics practices, such as electric or hydrogen-powered fleets, intermodal transportation, or collaborative urban delivery models, to reduce emissions and congestion.

4. Customer relations
The UAM can help manufacturing companies to analyze and enhance their customer-facing processes, from marketing and sales to after-sales service and support. By applying digital customer experience technologies, such as personalization, chatbots, or augmented reality, companies can improve the engagement, loyalty, and satisfaction of their customers. The UAM can also guide companies in developing data-driven customer insights and feedback loops, to continuously improve their products and services based on real-time customer needs and preferences.

By conducting a comprehensive business process assessment through the UAM framework, manufacturing companies can gain a holistic view of their operations, and identify the areas with the greatest potential for digital and green transformation. The UAM can provide guidance and support in designing and implementing new, digitally-enabled business processes, that are more efficient, agile, and sustainable, and that create new value for customers and stakeholders.

Moreover, the UAM can help manufacturing companies to measure and track the impact of their business process transformations, using a range of performance metrics and KPIs, such as:

1. Process cycle times and lead times
2. Inventory turns and working capital
3. On-time delivery and perfect order fulfillment
4. Customer satisfaction and Net Promoter Score
5. Carbon footprint and resource efficiency

By setting targets and monitoring progress on these metrics, manufacturing companies can ensure that their business process transformations are delivering tangible and measurable results, and contributing to their overall operational and financial performance.

In conclusion, the User Acceptance Model provides a powerful framework for manufacturing companies to assess, measure, and optimize the operational impact of their digital and green transformation initiatives. By focusing on two key aspects of operational impact - efficiency gains and business process transformation - the UAM can help companies to drive measurable improvements in their performance, competitiveness, and sustainability. Through the UAM efficiency assessment, manufacturing companies can identify and quantify the opportunities for reducing costs, waste, and resource consumption, and benchmark their performance against industry best practices. By implementing targeted efficiency measures and lean manufacturing practices, companies can achieve significant savings and productivity gains, while also improving their environmental sustainability and compliance. Through the UAM business process assessment, manufacturing companies can analyze and redesign their end-to-end operations, leveraging the power of digital technologies to create new value and competitive advantage. By implementing digitally-enabled processes in production, supply chain management, distribution, and customer relations, companies can improve their agility, flexibility, and responsiveness, while also reducing their environmental footprint and enhancing their customer experience.

The UAM provides a data-driven and metrics-based approach to track and measure the operational impact of digital and green transformation initiatives, enabling manufacturing companies to set ambitious yet achievable targets, monitor progress, and continuously improve their performance over time.

As manufacturing companies navigate the challenges and opportunities of Industry 4.0 and the sustainability imperative, embracing the User Acceptance Model can be a game-changer for their operational excellence and competitive advantage. By putting the UAM at the heart of their transformation strategy, and leveraging its tools and insights to drive efficiency gains and business process innovation, manufacturing companies can not only survive but thrive in the face of disruption and change, and create lasting value for their customers, employees, shareholders, and society as a whole.

4.1 Maturity and Readiness Levels

As manufacturing SMEs embark on their digital and green transformation journeys, it is crucial to assess their current maturity and readiness levels. The UAM provides a structured framework for evaluating an organization's progress and capabilities across various dimensions, using a clear and consistent set of stages and criteria.

The UAM defines four main stages of maturity and readiness: Basic, Explorative, Developing, and Advanced. Each stage represents a different level of sophistication, integration, and impact in terms of digital and green technology adoption, and is characterized by specific attributes and behaviours.

At the Basic stage, an SME has limited digital initiatives in place and low overall digital literacy. The company may have implemented some basic tools and systems, such as email and simple accounting software, but these are often used in an ad hoc and fragmented manner. There is little to no ambition or ability to digitalize key business processes, and the organization lacks a clear strategy or roadmap for digital transformation.

Similarly, from a sustainability perspective, an SME at the Basic stage has limited green initiatives and low environmental awareness. The company may be complying with basic regulations and standards, but there is no proactive effort to integrate sustainable practices into core operations. The organization lacks the ambition and ability to drive meaningful change, and any green initiatives are often reactive and isolated.

As an SME moves to the Explorative stage, it begins to demonstrate a stronger ambition and ability to explore digital and green opportunities. The company starts to investigate and pilot new technologies and practices, such as cloud computing, data analytics, or renewable energy. There is a growing recognition of the potential benefits and competitive advantages of digitalization and sustainability, but the organization may still be unsure of where to focus its efforts and how to scale up successful initiatives.

At this stage, an SME may have implemented some basic digital and green initiatives, such as a company website, social media presence, or recycling program, but these are often siloed and not fully integrated into core business processes. The organization may also be exploring partnerships and collaborations with external stakeholders, such as technology providers, sustainability consultants, or industry associations, to access new knowledge and resources.

As an SME progresses to the Developing stage, it begins to demonstrate a more strategic and systematic approach to digital and green transformation. The company has likely implemented several key initiatives and has achieved moderate levels of digital literacy and sustainability awareness across the organization. There is a clear ambition and ability to invest resources in digital and green technologies, and the organization has started to develop a more comprehensive strategy and roadmap for transformation.

At this stage, an SME may have implemented more advanced digital solutions, such as enterprise resource planning (ERP) systems, customer relationship management (CRM) platforms, or Internet of Things (IoT) technologies. The company may also have established more formal processes and structures for managing digital initiatives, such as a dedicated digital transformation team or a data governance framework.

From a sustainability perspective, an SME at the Developing stage has likely implemented several green initiatives, such as energy efficiency programs, sustainable sourcing practices, or circular economy projects. The company may also have started to measure and report on its environmental performance, using recognized frameworks and standards such as the Global Reporting Initiative (GRI) or the Carbon Disclosure Project (CDP).

Finally, at the Advanced stage, an SME has fully embedded digital and green initiatives into its core operations and has achieved significant levels of maturity and impact. Digital technologies are extensively leveraged and integrated across all business processes, and the organization has a strong ambition and ability to innovate and lead in the digital space. The company may have developed its own proprietary technologies or platforms and may be actively partnering with or acquiring other digital startups and innovators.

Similarly, from a sustainability perspective, an SME at the Advanced stage has fully integrated green initiatives into its business model and value chain. The company has a strong ambition and ability to innovate and lead in sustainable practices and may be setting new industry benchmarks and standards. Sustainability considerations are embedded into all decision-making processes, from product design and sourcing to manufacturing and logistics, and the organization may be actively collaborating with suppliers, customers, and other stakeholders to drive systemic change.

At this stage, an SME may have achieved significant reductions in its environmental footprint, such as becoming carbon neutral or zero waste, and may be using advanced technologies such as artificial intelligence (AI) and blockchain to optimize its operations and supply chain. The company may also be

exploring new business models and revenue streams based on sustainability, such as offering product-as-a-service or developing circular economy solutions.

To help SMEs assess their current maturity and readiness levels, the UAM provides a detailed set of criteria and indicators for each stage and dimension. For example, in the Basic stage, an SME may be characterized by having less than 20% of its processes digitalized, less than 10% of its employees with digital skills, and less than 5% of its energy from renewable sources. In contrast, an SME at the Advanced stage may have over 80% of its processes digitalized, over 50% of its employees with advanced digital skills, and over 50% of its energy from renewable sources.

By using these clear and measurable criteria, the UAM enables SMEs to benchmark their current performance against industry peers and best practices, identify key gaps and opportunities for improvement, and develop targeted strategies and roadmaps for digital and green transformation.

However, it is important to recognize that the UAM stages are not necessarily linear or sequential and that SMEs may be at different levels of maturity and readiness across different dimensions and functions. For example, an SME may be at the Advanced stage in terms of its digital marketing and e-commerce capabilities but at the Basic stage in terms of its supply chain sustainability practices. The UAM provides a flexible and adaptive framework that allows SMEs to focus on the areas that are most critical and relevant for their specific context and goals.

Moreover, the UAM emphasizes that digital and green transformation is not a one-time event but a continuous and iterative process of learning, experimentation, and improvement. As such, the model includes a strong focus on change management, culture, and leadership, recognizing that technology adoption alone is not sufficient for driving lasting and meaningful transformation.

SMEs are encouraged to use the UAM as a tool for regular self-assessment, benchmarking, and goal-setting, and to engage in ongoing dialogue and collaboration with internal and external stakeholders to drive progress and innovation. The model also provides guidance and resources for SMEs to build the necessary skills, capabilities, and partnerships to succeed in their digital and green transformation journeys.

The UAM provides a robust and comprehensive framework for assessing the maturity and readiness levels of manufacturing SMEs in their digital and green transformation journeys. By defining clear stages and criteria across various dimensions, the UAM enables organizations to benchmark their current performance, identify key gaps and opportunities, and develop targeted strategies and roadmaps for improvement. UAM aims to empower SMEs to embrace the full potential of digital and green technologies, driving innovation, competitiveness, and sustainability in the manufacturing sector.

4.2 Digital Technology Adoption

One of the key metrics used by the UAM to evaluate digital technology adoption is the extent of digital tool usage within an organization. This includes examining the breadth and depth of the company's digital toolkit, from basic productivity software and communication platforms to more advanced solutions like enterprise resource planning (ERP) systems, customer relationship management (CRM) software, and Internet of Things (IoT) technologies.

By mapping out the full range of digital tools and platforms used by an SME, the UAM can identify areas of strength and weakness, as well as opportunities for further integration and optimization. For example, a company may have a robust set of digital tools for financial management and accounting but lack the necessary solutions for supply chain coordination and logistics. By highlighting these gaps, the UAM can provide targeted recommendations for expanding and enhancing the organization's digital capabilities in a way that aligns with its specific business needs and priorities.

Another critical dimension of digital technology adoption assessed by the UAM is integration depth. This refers to the extent to which digital tools and platforms are seamlessly integrated into an organization's core business processes and workflows, as opposed to being used in a siloed or fragmented manner. Deep integration is essential for maximizing the benefits of digital technologies, as it enables real-time data sharing, collaboration, and decision-making across different functions and departments.

The UAM evaluates integration depth by examining how digital tools are being used to streamline and automate key processes, such as order processing, inventory management, production scheduling, and quality control. It also assesses the degree to which data from different systems and sources is being consolidated and analyzed to drive insights and improvements. By identifying areas where integration is lacking or inefficient, the UAM can provide recommendations for optimizing digital tool usage and achieving a more cohesive, coordinated digital ecosystem.

In addition to usage and integration, the UAM also focuses on the functionality enhancements provided by digital technologies. This includes assessing how digital tools are being leveraged to improve specific business capabilities, such as customer engagement, product innovation, and operational efficiency. For example, an SME may be using advanced analytics and machine learning algorithms to optimize production processes, reduce waste, and improve product quality. Or it may be using IoT sensors and real-time monitoring to enable predictive maintenance and minimize downtime.

By evaluating the specific functionality enhancements achieved through digital technology adoption, the UAM can help SMEs quantify the business value and ROI of their digital investments. This is critical for justifying continued investment in digital transformation initiatives and securing buy-in from key stakeholders, such as senior management, employees, and investors.

To provide more targeted and relevant recommendations, the UAM also takes into account industry-specific findings and best practices related to digital technology adoption. This recognizes the fact that different manufacturing sectors have unique challenges, opportunities, and requirements when it comes to digitalizing their operations.

For example, in the food and beverage industry, digital technologies like blockchain and IoT are being used to enable end-to-end traceability and food safety monitoring, from farm to fork. In the automotive sector, digital twins and virtual reality are being leveraged to optimize product design and testing, as well as to enable remote collaboration and training. By incorporating these industry-specific insights into its assessments and recommendations, the UAM can help SMEs benchmark their digital maturity against their peers and identify proven strategies for success.

Finally, the UAM emphasizes the importance of adopting a holistic, business-driven approach to digital technology adoption. Rather than pursuing digital initiatives in a piecemeal or technology-centric manner, the model encourages SMEs to align their digital strategies with their overall business objectives and value drivers. This means identifying the specific business processes and capabilities that are most critical for achieving competitive advantage and customer value, and then prioritizing digital investments and initiatives that directly support those areas.

For example, if an SME's primary goal is to improve customer satisfaction and loyalty, it may prioritize digital technologies that enhance the customer experience, such as mobile apps, personalization engines, and chatbots. If the main objective is to reduce costs and improve efficiency, the focus may be on digital solutions that automate manual processes, optimize resource utilization, and enable real-time monitoring and control.

By taking a business-driven approach to digital technology adoption, SMEs can ensure that their digital investments are targeted, impactful, and aligned with their strategic priorities. This helps to maximize the

value and ROI of digital initiatives, while also fostering a culture of innovation and continuous improvement that is essential for long-term success in the digital age.

The UAM provides a comprehensive and nuanced approach to assessing and promoting digital technology adoption among manufacturing SMEs. By evaluating key metrics such as usage, integration depth, and functionality enhancements, and by incorporating industry-specific insights and best practices, the UAM empowers companies to develop targeted, business-driven strategies for digital transformation. This enables SMEs to unlock the full potential of digital technologies for driving efficiency, innovation, and growth in an increasingly competitive and dynamic business environment.

4.3 Green Technology Adoption

One of the key areas of focus for the UAM is the adoption of renewable energy technologies. This includes evaluating an SME's current energy mix and identifying opportunities to shift towards cleaner, more sustainable sources such as solar, wind, hydro, and biomass. By conducting detailed energy audits and feasibility studies, the UAM can provide tailored recommendations for implementing renewable energy systems that are both environmentally friendly and cost-effective.

For example, an SME with a large rooftop area may be well-suited for installing solar panels, which can generate a significant portion of the company's electricity needs while reducing reliance on fossil fuels. Another SME with access to a steady supply of organic waste may benefit from investing in a biomass generator, which can convert the waste into clean energy and heat. By adopting renewable energy technologies, SMEs can not only reduce their carbon footprint but also achieve long-term cost savings and improve their energy security and resilience.

In addition to renewable energy, the UAM also emphasizes the importance of effective waste management and recycling practices. This includes assessing an SME's current waste streams and identifying opportunities for reducing, reusing, and recycling materials wherever possible. By conducting waste audits and mapping out the flow of materials through the organization, the UAM can provide recommendations for implementing more circular and sustainable waste management systems.

For example, an SME may identify opportunities to redesign its products and packaging to minimize waste and facilitate easier recycling at end-of-life. This could involve using more recyclable or biodegradable materials, implementing take-back programs for used products, or partnering with local recycling facilities to ensure proper disposal and processing of waste. By adopting a more circular approach to waste management, SMEs can reduce their environmental impact, conserve valuable resources, and potentially even generate new revenue streams from the sale of recycled materials.

Another critical aspect of green technology adoption assessed by the UAM is the sustainability of an organization's supply chain. This recognizes the fact that an SME's environmental footprint extends beyond its own operations and includes the impacts of its suppliers, distributors, and logistics partners. The UAM evaluates the extent to which an SME is engaging with its supply chain to promote sustainable practices, such as reducing greenhouse gas emissions, conserving water and energy, and sourcing responsibly.

This may involve conducting supplier audits and assessments to identify areas for improvement, setting sustainability performance targets and standards, and collaborating with suppliers to implement green technologies and best practices. For example, an SME may work with its logistics partners to optimize transportation routes and modes to minimize fuel consumption and emissions. Or it may partner with its raw material suppliers to develop more sustainable sourcing strategies, such as using recycled or bio-based materials, or supporting reforestation and biodiversity conservation efforts.

To provide a more holistic view of an SME's green technology adoption, the UAM also evaluates the organization's overall commitment to circular economy principles. This involves assessing the extent to which the company is designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. By embracing a circular economy approach, SMEs can not only reduce their environmental impact but also create new opportunities for innovation, growth, and long-term resilience.

For example, an SME may implement a product-as-a-service model, where customers pay for the use of a product rather than owning it outright. This incentivizes the company to design more durable, repairable, and recyclable products, as well as to develop efficient maintenance and refurbishment processes to keep the products in circulation for as long as possible. By shifting towards a more circular business model, SMEs can reduce their reliance on finite resources, generate recurring revenue streams, and build stronger, more loyal customer relationships.

To measure the impact and effectiveness of green technology adoption, the UAM emphasizes a range of key metrics and indicators. One of the most important of these is carbon footprint reduction, which measures the extent to which an SME is reducing its greenhouse gas emissions over time. This can be tracked through regular carbon audits and reporting, using standardized methodologies such as the Greenhouse Gas Protocol.

Another critical metric is resource efficiency, which measures how effectively an organization is using resources such as energy, water, and raw materials. This can be assessed through a variety of indicators, such as energy intensity (energy use per unit of output), water productivity (economic output per unit of water used), and material productivity (economic output per unit of material used). By setting targets and benchmarks for resource efficiency, SMEs can drive continuous improvement and identify opportunities for further optimization.

Finally, the UAM also emphasizes the importance of measuring and reporting on circular economy practices, such as the use of recycled or renewable materials, the implementation of take-back and recycling programs, and the adoption of product-as-a-service or other circular business models. By tracking these indicators over time, SMEs can demonstrate their progress towards a more circular and sustainable way of doing business, and communicate their achievements to stakeholders such as customers, investors, and regulators.

The User Acceptance Model provides a comprehensive and actionable framework for assessing and promoting green technology adoption among manufacturing SMEs. By focusing on key areas such as renewable energy, waste management, sustainable supply chains, and circular economy principles, and by emphasizing metrics such as carbon footprint reduction, resource efficiency, and circular economy practices, the UAM empowers companies to develop targeted, data-driven strategies for environmental sustainability. This enables SMEs to not only reduce their negative impact on the planet but also to create new opportunities for innovation, growth, and long-term value creation in a rapidly changing business landscape.

4.4 Support Services and Tools

One of the key support services provided by the UAM is consulting and advisory services. Many SMEs lack the in-house expertise and experience to effectively develop and execute a digital and green transformation strategy. They may struggle with questions such as where to start, what technologies to invest in, how to prioritize initiatives, and how to measure success. UAM consulting services can provide the guidance and support needed to answer these questions and drive progress.

UAM consultants bring deep industry knowledge and expertise to the table, having worked with a wide range of manufacturing SMEs across different sectors and geographies. They can help organizations assess their current maturity and readiness levels, identify key gaps and opportunities, and develop tailored strategies and roadmaps for transformation. This may involve conducting in-depth assessments and interviews,

facilitating workshops and brainstorming sessions, and providing ongoing coaching and mentoring to leaders and teams.

In addition to strategic planning, UAM consulting services can also support the implementation and operationalization of digital and green initiatives. This may include assistance with technology selection and procurement, project management and governance, change management and communication, and performance monitoring and reporting. By partnering with UAM consultants, SMEs can access the specialized skills and resources needed to drive successful execution and achieve tangible results.

Another key support service offered by the UAM is access to integrated technology platforms and solutions. The digital and green technology landscape is vast and complex, with hundreds of vendors and solutions competing for attention and market share. SMEs may struggle to navigate this landscape and identify the right tools and platforms for their specific needs and goals. The UAM can help simplify this process by recommending a curated set of integrated solutions that are specifically designed for manufacturing SMEs.

These solutions may include cloud-based platforms for data management and analytics, IoT and sensor technologies for real-time monitoring and optimization, 3D printing and additive manufacturing solutions for prototyping and production, and circular economy software for tracking and managing material flows and waste streams. By leveraging these integrated platforms, SMEs can accelerate their digital and green transformation efforts, while reducing the complexity and cost of managing multiple disparate systems.

The UAM may also offer training and certification programs to help SMEs build the necessary skills and capabilities to effectively use and maintain these technology solutions. This may include online courses, hands-on workshops, and peer-to-peer learning opportunities, as well as certification programs that validate an organization's proficiency and mastery of specific tools and methodologies.

In addition to technology solutions, the UAM also provides a range of tools and resources for performance benchmarking and continuous improvement. One of the key challenges for SMEs in their digital and green transformation journeys is knowing how they compare to their industry peers and what "good" looks like. The UAM offers a suite of benchmarking tools and databases that allow organizations to track their performance against industry standards and best practices.

These tools may include maturity assessments, key performance indicators (KPIs), and scorecards that measure progress across various dimensions of digital and green transformation, such as energy efficiency, waste reduction, data analytics, and customer experience. By regularly monitoring and reporting on these metrics, SMEs can identify areas for improvement, set targets and goals, and track their progress over time.

The UAM may also facilitate peer-to-peer benchmarking and knowledge-sharing opportunities, such as industry forums, workshops, and case study presentations. These events allow SMEs to learn from the successes and failures of others, share best practices and lessons learned, and build a community of practice around digital and green transformation.

Another important support service offered by the UAM is innovation and collaboration support. Many SMEs struggle to keep up with the rapid pace of technological change and may lack the resources and capabilities to develop and scale new solutions on their own. The UAM can help bridge this gap by connecting SMEs with a wider ecosystem of partners and stakeholders, including technology providers, research institutions, startups, and other industry players.

The UAM may offer innovation scouting and matchmaking services, helping SMEs identify and engage with potential partners and collaborators based on their specific needs and interests. This may involve facilitating introductions and meetings, providing guidance on intellectual property and legal issues, and supporting the development of joint projects and initiatives.

The UAM may also provide access to funding and investment opportunities, such as grants, loans, and venture capital, to help SMEs finance their innovation and growth efforts. This may involve partnering with government agencies, financial institutions, and impact investors to create targeted funding programs and investment vehicles for digital and green transformation in the manufacturing sector.

In addition to these core support services and tools, the UAM may offer a range of other resources and solutions based on the evolving needs and priorities of manufacturing SMEs. These may include:

1. **Legal and regulatory compliance support**
Helping SMEs navigate the complex and changing landscape of laws and regulations related to data privacy, cybersecurity, environmental sustainability, and other key areas.

2. **Supply chain optimization and collaboration**
Providing tools and services to help SMEs optimize their supply chain operations, improve visibility and traceability, and collaborate more effectively with suppliers and partners.

3. **Customer experience and engagement**
Offering solutions and strategies to help SMEs better understand and engage with their customers, using digital technologies such as social media, mobile apps, and customer analytics.

4. **Talent and workforce development**
Supporting SMEs in attracting, developing, and retaining the skilled talent needed to drive digital and green transformation, through initiatives such as apprenticeships, training programs, and diversity and inclusion efforts.

5. **Crisis management and resilience**
Helping SMEs prepare for and respond to unexpected disruptions and crises, such as natural disasters, cyber-attacks, or supply chain interruptions, through risk assessment, scenario planning, and business continuity services.

The goal of the UAM support services and tools is to empower manufacturing SMEs to succeed in their digital and green transformation journeys, by providing the knowledge, resources, and capabilities needed to drive innovation, competitiveness, and sustainability. By leveraging these services and tools, SMEs can accelerate their progress and impact, while reducing the risks and costs associated with going it alone. However, it is important to recognize that no two SMEs are alike, and that the specific support needs and priorities may vary significantly based on factors such as industry sector, company size, geographic location, and maturity level. As such, the UAM takes a highly customized and collaborative approach to working with SMEs, tailoring its services and solutions to the unique needs and goals of each organization. This may involve conducting in-depth assessments and interviews to understand the SME's current state and future aspirations, co-creating roadmaps and action plans that align with the organization's culture and values, and providing ongoing support and coaching to help leaders and teams navigate the challenges and opportunities of transformation.

The UAM also recognizes that digital and green transformation is not a one-time event, but rather a continuous journey of learning, experimentation, and improvement. As such, the model emphasizes the importance of building a culture of innovation and agility within SMEs, where employees at all levels are empowered to think creatively, take risks, and drive change.

To support this culture of innovation, the UAM may offer training and development programs that focus on skills such as design thinking, agile methodology, and change management. It may also facilitate cross-

functional collaboration and knowledge-sharing within and across organizations, through initiatives such as hackathons, innovation challenges, and communities of practice.

The success of digital and green transformation in the manufacturing sector will depend not only on the adoption of new technologies and practices but also on the ability of SMEs to fundamentally reimagine their business models, value propositions, and relationships with customers, employees, and partners. The UAM support services and tools aim to help organizations make this shift, by providing the insights, capabilities, and confidence needed to thrive in a rapidly changing world.

The UAM offers a comprehensive and holistic approach to supporting manufacturing SMEs in their digital and green transformation journeys. Through a range of consulting, technology, benchmarking, innovation, and other support services and tools, the UAM empowers organizations to achieve their goals and drive meaningful change. By leveraging these resources and partnering with the UAM, manufacturing SMEs can position themselves for success in the years and decades to come, as they navigate the challenges and opportunities of Industry 4.0 and the circular economy.

4.5 The Human Element

One of the most critical aspects of the human element in the UAM is the attitudes and perceptions of employees and management towards digital and green initiatives. The UAM assessment process has revealed a wide range of attitudes, from enthusiastic support and engagement to skepticism and resistance, depending on various factors such as the individual's role, experience, and understanding of the initiatives. On one end of the spectrum, there are employees and managers who recognize the potential benefits and opportunities of digital and green transformation, such as increased efficiency, competitiveness, and sustainability, and who are willing to embrace and drive these changes. These individuals often have a clear vision and understanding of the strategic importance of digital and green initiatives, and are able to communicate and cascade this vision throughout the organization.

On the other end of the spectrum, there are employees and managers who are resistant or skeptical towards digital and green initiatives, often due to psychological and cultural barriers such as fear of change, lack of trust, or perceived threat to their job security and status quo. These individuals may view digital and green technologies as a disruption or a burden, rather than an opportunity, and may be hesitant to invest time and resources in learning and adopting new skills and practices. They may also have concerns about the reliability, security, and ethical implications of digital and green technologies, such as data privacy, cybersecurity, or job displacement.

The UAM testing process has also highlighted some common barriers that manufacturing companies face in engaging and motivating their employees and management towards digital and green transformation. One of the most significant barriers is the lack of financial resources and incentives to support the adoption and implementation of digital and green technologies and practices. Many companies, especially small and medium-sized enterprises (SMEs), struggle to allocate sufficient budget and resources for training, equipment, and infrastructure related to digital and green initiatives, due to competing priorities and limited cash flow. This lack of financial support can create a vicious cycle, where employees and managers are unable to develop the necessary skills and capabilities to drive digital and green transformation, which in turn limits the company's ability to generate value and return on investment from these initiatives.

Another common barrier is the lack of expertise and knowledge related to digital and green technologies and practices, both among employees and management. The UAM assessment process has revealed significant gaps and inconsistencies in the level of digital and green literacy and competency across different functions and levels of the organization. Many employees and managers lack the basic understanding and skills needed to effectively use and integrate digital and green technologies in their daily work, such as data analytics, automation, sustainability assessment, or circular economy principles. This lack of expertise can

lead to resistance, confusion, and inefficiencies in the adoption and implementation of digital and green initiatives, and can hinder the company's ability to leverage these technologies for innovation and competitive advantage.

Furthermore, the UAM has identified resistance to change as a major cultural barrier to digital and green transformation. Many employees and managers are comfortable with the status quo and are resistant to new ways of working and thinking, even when presented with evidence of the potential benefits and opportunities. This resistance can stem from various factors, such as fear of failure, lack of motivation, or perceived loss of control and autonomy. It can also be reinforced by organizational cultures that are hierarchical, siloed, or risk-averse, and that do not encourage experimentation, collaboration, and continuous learning. Overcoming this resistance requires a significant shift in mindset and behavior, as well as a supportive and enabling environment that promotes trust, transparency, and empowerment.

Despite these barriers, the UAM testing process has also identified several key facilitators that can help manufacturing companies to engage and motivate their employees and management towards digital and green transformation. One of the most important facilitators is leadership support and commitment, both at the top management and middle management levels. Leaders who are visionary, inspiring, and supportive of digital and green initiatives can play a crucial role in creating a sense of urgency, purpose, and direction for the organization, and in mobilizing and empowering employees to take ownership and action. They can also lead by example, by demonstrating the behaviors and values that are consistent with digital and green transformation, such as agility, innovation, sustainability, and collaboration.

Another key facilitator is the presence of regulatory incentives and pressures, which can create a compelling case and motivation for manufacturing companies to adopt and integrate digital and green technologies and practices. Governments and industry bodies are increasingly setting targets, standards, and regulations related to digitalization, sustainability, and circular economy, which can drive companies to invest in and prioritize these initiatives. For example, the European Green Deal and the Circular Economy Action Plan set ambitious goals and measures to promote the twin transition towards a digital and sustainable economy, and provide various funding and support mechanisms for companies to align with these goals. Similarly, the EU Taxonomy for Sustainable Activities and the Corporate Sustainability Reporting Directive create a framework and incentives for companies to assess and disclose their environmental and social performance, and to integrate sustainability into their business models and strategies.

The UAM testing process has also highlighted the importance of employee engagement and participation in driving digital and green transformation. Companies that actively involve and empower their employees in the design, implementation, and monitoring of digital and green initiatives are more likely to achieve buy-in, ownership, and continuous improvement. This can be achieved through various mechanisms, such as regular communication and feedback loops, cross-functional teams and projects, innovation challenges and hackathons, or employee-driven sustainability initiatives. By giving employees a voice and a stake in the transformation process, companies can tap into their creativity, expertise, and motivation, and can foster a culture of learning, experimentation, and collaboration.

Finally, the UAM has identified the role of external partnerships and ecosystems in facilitating digital and green transformation. Manufacturing companies that collaborate and engage with external stakeholders, such as technology providers, research institutions, industry associations, or sustainability experts, can access valuable knowledge, resources, and capabilities that complement and enhance their internal efforts. These partnerships can take various forms, such as joint research and development projects, pilot and demonstration initiatives, training and education programs, or supply chain collaborations. By leveraging the expertise and assets of external partners, manufacturing companies can accelerate their learning curve, reduce their risks and costs, and create shared value and impact.

The human element is a critical component of the User Acceptance Model, and plays a significant role in shaping the success and sustainability of digital and green transformation in manufacturing companies. The UAM testing process has revealed a wide range of attitudes, barriers, and facilitators that influence the adoption and integration of digital and green technologies and practices, and that require a holistic and tailored approach to address them. Manufacturing companies that prioritize and invest in the human element, by engaging and empowering their employees and management, creating a supportive and enabling culture, and leveraging external partnerships and incentives, are more likely to achieve the full potential and benefits of digital and green transformation. By putting people at the center of their transformation strategy, these companies can not only improve their operational and financial performance, but also create a more rewarding, meaningful, and sustainable work environment for their employees, and contribute to the wider societal and environmental goals of the industry and beyond.

E. Conclusion

UAM testing process has yielded a wealth of valuable insights and critical discoveries that have significant implications for the future of digital and green transformation in the manufacturing industry. This section will provide a comprehensive summary of these key findings and discuss their potential impact on manufacturing SMEs, the UAM framework, and the broader ecosystem of stakeholders involved in the twin transition.

One of the most critical discoveries from the UAM testing process is the confirmation that manufacturing SMEs are at different stages of their digital and green transformation journey, with varying levels of maturity, readiness, and capability across different dimensions. While some SMEs have already made significant progress in adopting advanced technologies and sustainable practices, others are still in the early stages of exploration and experimentation. This finding highlights the need for a more nuanced and tailored approach to supporting SMEs in their twin transition, one that recognizes and addresses their specific needs, challenges, and aspirations at each stage of the journey.

The implications of this discovery are far-reaching and profound. First, it suggests that a one-size-fits-all approach to the UAM framework may not be effective in capturing the diversity and complexity of SMEs' maturity levels and transformation paths. Instead, the UAM needs to adopt a more modular and adaptive structure that allows for customization and prioritization based on the SME's profile, context, and goals. This could involve developing a set of core and optional modules that cover different aspects of digital and green transformation, such as strategy, technology, skills, operations, and ecosystem, and that can be selected and combined based on the SME's specific needs and priorities.

Second, this discovery implies that SMEs at different maturity levels may require different types and levels of support, resources, and incentives to advance their digital and green transformation. For instance, SMEs at the early stages may need more basic and foundational support, such as awareness-raising, digital literacy training, and environmental impact assessment, while SMEs at the advanced stages may need more specialized and strategic support, such as technology integration, circular economy implementation, and ecosystem collaboration. This calls for a more targeted and differentiated approach to the UAM recommendations and support mechanisms, one that matches the SME's maturity level and transformation stage with the appropriate tools, guidance, and resources.

Third, this discovery suggests that the UAM framework needs to be more dynamic and iterative, allowing for continuous assessment, feedback, and improvement based on the SMEs' progress and experiences. As SMEs advance along their transformation journey, their needs, challenges, and priorities may evolve and change, requiring a more agile and responsive approach to the UAM framework. This could involve establishing feedback loops and learning mechanisms that enable SMEs to share their successes, failures, and lessons learned, and that inform the continuous refinement and adaptation of the UAM questions, metrics, and recommendations.

Another critical discovery from the UAM testing process is the identification of common barriers, enablers, and best practices for digital and green transformation among manufacturing SMEs. While the specific challenges and opportunities may vary depending on the SME's sector, size, location, and maturity level, the testing process has revealed some recurring themes and patterns that cut across different contexts and stages of the transformation journey.

On the barriers side, many SMEs have reported challenges related to the lack of awareness, skills, and resources for digital and green transformation. They often struggle with understanding the business case and benefits of adopting new technologies and sustainable practices, and with accessing the necessary funding, talent, and infrastructure to implement and scale these initiatives. They also face difficulties in

navigating the complex and fragmented landscape of standards, regulations, and incentives for digital and green transformation, which can create confusion, duplication, and uncertainty.

On the enablers side, the testing process has highlighted the importance of leadership, culture, and collaboration for successful digital and green transformation. SMEs that have made significant progress often credit the vision, commitment, and support of their top management, as well as the engagement, creativity, and ownership of their employees, as key success factors. They also emphasize the value of collaborating and partnering with external stakeholders, such as technology providers, industry associations, academia, and government agencies, to access new knowledge, resources, and opportunities for innovation and growth.

In terms of best practices, the testing process has identified several common approaches and strategies that have proven effective for SMEs in advancing their digital and green transformation. These include:

- Developing a clear and compelling vision and strategy for digital and green transformation, aligned with the SME's business objectives and values, and communicated and cascaded throughout the organization.
- Conducting a thorough assessment and mapping of the SME's current state, capabilities, and gaps in digital and green transformation, using the UAM framework or other relevant tools and benchmarks.
- Prioritizing and sequencing the digital and green initiatives based on their impact, feasibility, and alignment with the SME's vision and strategy, and developing a roadmap and action plan for implementation.
- Investing in the necessary skills, talent, and infrastructure for digital and green transformation, through a combination of training, recruitment, and partnerships, and fostering a culture of learning, experimentation, and innovation.
- Measuring and communicating the progress and impact of digital and green initiatives, using relevant and meaningful metrics and indicators, and celebrating and sharing the successes and lessons learned with internal and external stakeholders.
- Engaging and collaborating with the broader ecosystem of stakeholders, such as customers, suppliers, peers, and policymakers, to co-create and scale digital and green solutions, and to shape the enabling environment and incentives for the twin transition.

The implications of these common barriers, enablers, and best practices are significant for the UAM framework and the broader ecosystem of stakeholders involved in the twin transition. They suggest that the UAM needs to provide more than just an assessment and recommendation tool for SMEs, but also a platform and catalyst for awareness-raising, capacity-building, and collaboration among different actors and sectors:

- Developing and disseminating more targeted and actionable communication and education materials on the business case, benefits, and opportunities of digital and green transformation, tailored to different SME profiles and maturity levels.
- Establishing and facilitating more peer learning and networking opportunities for SMEs to share their experiences, challenges, and best practices, and to build a community of practice and support for the twin transition.
- Strengthening and aligning the enabling environment and incentives for digital and green transformation, through more coordinated and coherent policies, regulations, standards, and funding mechanisms, at the local, national, and European levels.
- Fostering more open and collaborative innovation ecosystems, where SMEs can access and leverage the knowledge, resources, and capabilities of different stakeholders, such as technology providers, service providers, universities, and civil society organizations, to co-create and scale digital and green solutions.

The key discoveries and implications from the UAM testing process provide a rich and nuanced understanding of the current state, challenges, and opportunities of digital and green transformation in the manufacturing industry, particularly among SMEs. They highlight the need for a more tailored, dynamic, and

collaborative approach to the UAM framework and the broader ecosystem of stakeholders, one that recognizes and addresses the diversity and complexity of SMEs' maturity levels, transformation paths, and support needs. They also underscore the importance of fostering a culture of learning, experimentation, and collaboration, both within and across organizations and sectors, to accelerate and scale the twin transition towards a more sustainable, resilient, and competitive manufacturing industry.

To realize these implications and achieve the full potential of the UAM framework and the twin transition, it is essential for manufacturing SMEs, policymakers, industry associations, technology providers, academia, and civil society organizations to work together and align their efforts and resources towards a common vision and roadmap for the future of manufacturing. This could involve:

- Establishing a multi-stakeholder platform or alliance for the twin transition in manufacturing, that brings together different actors and sectors to co-create and implement a shared vision, strategy, and action plan for digital and green transformation, at the local, national, and European levels.
- Developing and piloting more innovative and impactful support mechanisms and instruments for SMEs, such as digital and green innovation hubs, vouchers, mentoring, and coaching, that leverage the expertise and resources of different stakeholders and provide more targeted and integrated support for the twin transition.
- Investing in more research, development, and demonstration projects and infrastructures for digital and green technologies and solutions in manufacturing, that enable SMEs to experiment, validate, and scale their initiatives, and that foster more open and collaborative innovation ecosystems.
- Promoting more awareness, education, and skills development programs and initiatives for the twin transition in manufacturing, that reach and engage different target groups and levels, from students and workers to managers and policymakers, and that build the necessary competencies and mindsets for the future of manufacturing.

By working together and leveraging the critical discoveries and implications from the UAM testing process, manufacturing SMEs and the broader ecosystem of stakeholders can accelerate and scale the digital and green transformation of the manufacturing industry, and contribute to a more sustainable, resilient, and competitive future for Europe and beyond. The UAM framework can play a key role in this process, by providing a common language, framework, and platform for assessment, recommendation, and collaboration, and by inspiring and guiding manufacturing SMEs and stakeholders towards a shared vision and ambition for the twin transition.

5.1 Wider importance of UAM in catalyzing digital and sustainable changes

At its core, the UAM framework provides a comprehensive and structured approach for manufacturing SMEs to assess their current state of digital and green maturity, identify their strengths and gaps, and develop targeted strategies and roadmaps for improvement. By doing so, the UAM helps SMEs to navigate the complex and rapidly evolving landscape of digital and sustainable technologies and practices, and to prioritize and implement the most relevant and impactful initiatives for their specific context and goals. This, in turn, enables SMEs to enhance their competitiveness, resilience, and sustainability, and to create value for their customers, employees, and communities.

However, the benefits and impacts of the UAM framework extend far beyond the individual SMEs that use it. By providing a common language, framework, and platform for digital and green transformation, the UAM has the potential to catalyze wider changes and collaborations across the manufacturing industry and the broader ecosystem of stakeholders. This is particularly important in the context of the twin transition, which requires a systemic and coordinated approach to address the complex and interconnected challenges of digitalization and sustainability, such as skills development, infrastructure investment, regulatory alignment, and societal acceptance.

One of the key ways in which the UAM can catalyze wider digital and sustainable changes is by fostering a culture of continuous learning, experimentation, and collaboration among manufacturing SMEs. Through the UAM testing and recommendation process, SMEs are encouraged to reflect on their current practices and performance, identify areas for improvement, and explore new technologies and business models. This process of self-reflection and exploration can help SMEs to break out of their traditional silos and mindsets, and to embrace a more open and innovative approach to digital and green transformation.

Moreover, by participating in the UAM framework, SMEs can access a wealth of knowledge, resources, and best practices from other companies, experts, and stakeholders involved in the twin transition. The UAM platform can serve as a hub for peer learning, networking, and collaboration, where SMEs can share their experiences, challenges, and solutions, and learn from each other's successes and failures. This collaborative approach can help to accelerate the adoption and diffusion of digital and sustainable technologies and practices across the manufacturing industry, and to create a virtuous cycle of innovation and improvement.

Another way in which the UAM can catalyze wider digital and sustainable changes is by providing a common framework and evidence base for policymakers, technology providers, and other stakeholders to support and invest in the twin transition. The data and insights generated through the UAM assessment and recommendation process can help to identify the key barriers, enablers, and opportunities for digital and green transformation in the manufacturing industry, and to inform the development of targeted policies, programs, and solutions.

For example, policymakers can use the UAM data to identify the skills and infrastructure gaps that need to be addressed to support the twin transition, and to design and implement more effective education, training, and investment policies. Technology providers can use the UAM insights to develop and market more relevant and user-friendly digital and sustainable solutions for manufacturing SMEs, and to co-create and test these solutions with the end-users. Industry associations and clusters can use the UAM framework to benchmark and support their members in the twin transition, and to facilitate more collaboration and knowledge-sharing across the value chain.

Furthermore, the UAM can help to raise awareness and understanding of the importance and benefits of digital and sustainable transformation among a wider audience, including investors, consumers, and the general public. By showcasing the progress and impact of manufacturing SMEs in the twin transition, the UAM can help to build trust and confidence in the industry's ability to deliver on its social and environmental responsibilities, and to create value for all stakeholders. This, in turn, can help to attract more investment, talent, and support for the manufacturing industry, and to accelerate the transition towards a more sustainable and competitive future.

Finally, the UAM framework can contribute to the wider global agenda and efforts for sustainable development and climate action. The manufacturing industry plays a critical role in achieving the United Nations Sustainable Development Goals (SDGs) and the Paris Agreement on climate change, as it is responsible for a significant share of global resource consumption, emissions, and waste. By supporting manufacturing SMEs in their digital and green transformation, the UAM can help to reduce the industry's environmental footprint, improve its social impact, and contribute to the achievement of the SDGs and climate targets.

Moreover, the UAM framework can serve as a model and inspiration for other industries and sectors to adopt similar approaches and tools for digital and sustainable transformation. The lessons learned and best practices generated through the UAM process can be shared and adapted to other contexts and challenges, such as the digital and green transformation of agriculture, energy, transport, and cities. This can help to create a more systemic and integrated approach to sustainable development, and to accelerate the transition towards a more resilient, inclusive, and low-carbon economy and society.

In conclusion, the wider importance of the UAM framework in catalyzing digital and sustainable changes cannot be overstated. By providing a common language, framework, and platform for assessment, recommendation, and collaboration, the UAM has the potential to drive systemic and transformative changes across the manufacturing industry and the broader ecosystem of stakeholders involved in the twin transition. It can help to foster a culture of continuous learning, experimentation, and collaboration among manufacturing SMEs, to inform and support the development of targeted policies, programs, and solutions, and to raise awareness and understanding of the importance and benefits of digital and sustainable transformation among a wider audience.

The UAM framework can contribute to the wider global agenda and efforts for sustainable development and climate action, by supporting the manufacturing industry in reducing its environmental footprint, improving its social impact, and achieving the SDGs and climate targets. It can also serve as a model and inspiration for other industries and sectors to adopt similar approaches and tools for digital and sustainable transformation, and to create a more systemic and integrated approach to sustainable development.

To fully realize the wider importance and potential of the UAM framework, it is essential for manufacturing companies, policymakers, technology providers, and other stakeholders to work together and align their efforts and resources towards a common vision and roadmap for the twin transition. This could involve:

- Scaling up the adoption and use of the UAM framework across the manufacturing industry, by raising awareness, providing incentives, and supporting the implementation of the UAM assessment and recommendation process.
- Strengthening the collaboration and knowledge-sharing among manufacturing SMEs, experts, and stakeholders involved in the UAM framework, by creating more opportunities for peer learning, networking, and co-creation.
- Aligning the policies, programs, and investments in support of the twin transition with the insights and recommendations generated through the UAM framework, by using the UAM data and evidence to inform and guide the decision-making process.
- Communicating and disseminating the progress and impact of manufacturing SMEs in the twin transition, by using the UAM framework to track and report on the key performance indicators and success stories, and to engage and inspire a wider audience.
- Adapting and replicating the UAM framework to other industries and sectors, by sharing the lessons learned and best practices, and by co-designing and piloting similar approaches and tools for digital and sustainable transformation.

Manufacturing companies and the broader ecosystem of stakeholders can accelerate and scale the digital and sustainable transformation of the industry, and contribute to a more resilient, inclusive, and low-carbon future for all. The UAM framework can play a key role in this process, by providing a common language, framework, and platform for assessment, recommendation, and collaboration, and by inspiring and guiding the manufacturing industry towards a more sustainable and competitive future.

5.2 Strategic Planning and Recommendations

When it comes to driving digital and green transitions in manufacturing SMEs, having a clear and actionable strategic plan is crucial. The UAM provides a comprehensive framework for assessing an organization's current state of readiness and maturity, identifying areas for improvement, and developing tailored recommendations to support their transformation journey.

One of the key strengths of the UAM is its ability to generate customized action plans based on the specific results of each company's assessment. By analyzing the data collected through interviews, surveys, and other methods, the UAM can pinpoint the unique challenges, opportunities, and priorities facing each SME.

This allows for the development of targeted strategies that address the company's specific needs and goals, rather than a one-size-fits-all approach.

For example, an SME that scores high on digital readiness but low on sustainability measures might receive a plan focused on leveraging their existing technology capabilities to drive green initiatives, such as implementing IoT sensors to monitor and optimize energy consumption. On the other hand, a company with strong sustainability practices but limited digital adoption might receive recommendations centered on integrating digital tools to streamline and scale their eco-friendly efforts.

In addition to these customized plans, the UAM also emphasizes the importance of training and skill development in supporting successful transformations. Many SMEs face significant challenges in terms of workforce readiness and expertise, particularly when it comes to emerging technologies and sustainable practices. To address these gaps, the UAM recommends a range of training programs and resources tailored to the specific needs of each organization and its employees. This could include online courses and workshops on topics like data analytics, automation, circular economy principles, and green supply chain management, as well as on-the-job training and mentorship opportunities to help workers apply these concepts in practice. By investing in the skills and knowledge of their people, SMEs can foster a culture of continuous learning and innovation, which is essential for staying competitive in today's rapidly evolving business landscape.

Another critical aspect of the UAM's strategic planning and recommendations is the focus on financial assistance and support. Implementing digital and green technologies often requires significant upfront investments, which can be a major barrier for many SMEs with limited resources. To help overcome these challenges, the UAM identifies potential funding sources and financing options, such as government grants, low-interest loans, and tax incentives specifically designed to support sustainability and digitalization efforts.

The model also provides guidance on building strong business cases and return-on-investment (ROI) analyses to help SMEs justify and prioritize their technology investments. By quantifying the potential benefits and cost savings associated with different initiatives, companies can make more informed decisions about where to allocate their resources for maximum impact.

In addition to financial assistance, the UAM also emphasizes the importance of technology partnerships and strategic planning services in supporting SMEs' transformation efforts. Many smaller companies lack the in-house expertise and capacity to effectively evaluate, implement, and manage complex digital and green solutions. By connecting SMEs with trusted technology vendors, service providers, and consultants, the UAM helps to bridge these gaps and provide access to the tools, platforms, and support needed to drive successful transitions. This could include assistance with vendor selection and procurement, systems integration and deployment, data management and analytics, and ongoing maintenance and optimization. By leveraging the expertise of these external partners, SMEs can accelerate their adoption of digital and green technologies, while also freeing up internal resources to focus on core business activities.

The model recognizes that digital and green transformation is not a one-time event, but rather an ongoing journey that requires regular assessment, adjustment, and optimization. To support this process, the UAM provides tools and frameworks for tracking progress, measuring impact, and identifying new opportunities for growth and innovation. This could include regular check-ins and follow-up assessments to monitor implementation and outcomes, as well as benchmarking against industry peers and best practices. By embedding a culture of continuous improvement and data-driven decision-making, SMEs can ensure that their strategic plans remain relevant, agile, and responsive to changing market conditions and stakeholder expectations.

By offering customized action plans, targeted training and skill development, financial assistance and support, technology partnerships and strategic planning services, and a focus on continuous improvement,

the UAM empowers companies to drive meaningful, sustainable change and stay ahead of the curve in an increasingly competitive and dynamic business environment.

5.3 Monitoring and Improvement

At the heart of the UAM's approach to monitoring and improvement is a strong framework for tracking progress and measuring impact. This framework establishes clear metrics and key performance indicators (KPIs) that are tailored to the specific goals and objectives of each SME's digital and green transformation journey. For example, an SME focused on improving energy efficiency may track metrics such as energy consumption per unit of production, greenhouse gas emissions, and renewable energy usage. An SME looking to enhance its customer experience through digital channels may monitor metrics such as website traffic, customer satisfaction scores, and online conversion rates.

The UAM works closely with SMEs to identify the most relevant and meaningful metrics for their unique context and to establish baseline measurements and targets for improvement. This collaborative process helps ensure that monitoring efforts are focused on the areas that matter most to the business and that progress can be accurately tracked over time. Once the monitoring framework is in place, the UAM provides a range of tools and technologies to support ongoing data collection, analysis, and reporting. This may include IoT sensors and devices for real-time monitoring of equipment performance and energy usage, data analytics platforms for aggregating and visualizing data from multiple sources, and dashboard and reporting tools for communicating progress to stakeholders.

The UAM also emphasizes the importance of regular review and evaluation of monitoring data to identify trends, patterns, and opportunities for improvement. This may involve conducting periodic assessments or audits to validate data accuracy and reliability, as well as holding regular performance review meetings with cross-functional teams to discuss progress, challenges, and next steps. However, monitoring alone is not enough to drive continuous improvement. The UAM recognizes that true progress requires a culture of openness, transparency, and accountability, where employees at all levels are encouraged to share their ideas, feedback, and concerns. To support this culture, the UAM helps SMEs implement a range of feedback mechanisms and channels, both formal and informal.

This may include regular employee surveys and focus groups to gather input on the effectiveness of digital and green initiatives, as well as more casual touchpoints such as "town hall" meetings, "lunch and learn" sessions, and online forums for sharing best practices and lessons learned. By actively seeking and valuing employee feedback, SMEs can foster a sense of ownership and engagement in the transformation process and ensure that initiatives remain grounded in the day-to-day realities of the business.

The UAM also stresses the importance of customer and stakeholder feedback in driving continuous improvement. This may involve conducting regular surveys or interviews with customers to understand their evolving needs and preferences, as well as engaging with suppliers, partners, and other external stakeholders to gather input on industry trends, emerging technologies, and potential collaboration opportunities.

To help SMEs make sense of all this feedback and translate it into actionable insights, the UAM provides a structured approach to continuous improvement that is grounded in proven methodologies such as lean, six sigma, and agile. This approach emphasizes the importance of rapid experimentation, iterative testing, and data-driven decision making to drive ongoing optimization and innovation. For example, an SME may use agile methodologies to quickly prototype and test new digital solutions with a subset of customers or employees, gathering real-time feedback and making rapid adjustments based on user input. Or it may apply lean principles to identify and eliminate waste in its production processes, using data from IoT sensors and other monitoring tools to pinpoint areas for improvement.

The UAM also recognizes that continuous improvement is not a one-size-fits-all process and that SMEs may have different levels of maturity and readiness when it comes to embracing change. As such, the model provides a range of support options and resources to help organizations build the skills, capabilities, and culture needed to sustain ongoing improvement efforts. This may include training and coaching programs to help employees develop new skills and adapt to new ways of working, as well as access to best practices, case studies, and peer networks to facilitate knowledge-sharing and collaboration. The UAM may also provide more hands-on support and guidance for SMEs that are just starting out on their continuous improvement journey, such as facilitated workshops, on-site assessments, and dedicated project support.

Ultimately, the goal of the UAM's monitoring and improvement framework is to help SMEs build a culture of excellence and innovation that permeates every aspect of the business. By embedding data-driven decision making, rapid experimentation, and ongoing feedback into the fabric of the organization, SMEs can develop the agility and resilience needed to thrive in an increasingly complex and dynamic business environment.

The UAM also recognizes that continuous improvement is not just about internal processes and metrics but also about external impact and value creation. As such, the model encourages SMEs to think beyond their own organizational boundaries and consider how their digital and green transformation efforts can contribute to broader societal and environmental goals. This can involve aligning continuous improvement efforts with global sustainability frameworks such as the United Nations Sustainable Development Goals (SDGs), as well as collaborating with industry partners, policymakers, and civil society organizations to drive systemic change. By taking a more holistic and stakeholder-centric approach to continuous improvement, SMEs can not only enhance their own competitiveness and resilience but also play a vital role in shaping a more sustainable and inclusive future for all.

Of course, the journey of continuous improvement is not without its challenges and obstacles. SMEs may face resistance to change from employees or stakeholders who are comfortable with the status quo, as well as resource constraints and competing priorities that can make it difficult to sustain momentum over time. To help SMEs navigate these challenges, the UAM provides ongoing support and guidance in the form of coaching, mentoring, and troubleshooting services. This may involve working with leadership teams to develop and communicate a compelling vision for change, as well as providing tactical support and advice to help teams overcome specific roadblocks or barriers.

The UAM also emphasizes the importance of celebrating successes and milestones along the way, as well as learning from failures and setbacks. By creating a culture that values experimentation, risk-taking, and continuous learning, SMEs can build the resilience and adaptability needed to weather the inevitable ups and downs of the transformation journey. Ultimately, the success of any continuous improvement effort depends on the commitment and engagement of every individual within the organization. The UAM recognizes this and works to empower employees at all levels to take ownership of their own learning and development, as well as to contribute their unique skills and perspectives to the collective effort.

This can involve providing opportunities for cross-functional collaboration and knowledge-sharing, as well as recognizing and rewarding employees who demonstrate exceptional leadership, innovation, and impact in their work. By building a culture of shared ownership and accountability, SMEs can tap into the full potential of their human capital and drive sustained performance improvement over time.

The UAM provides a comprehensive and holistic approach to monitoring and continuous improvement for manufacturing SMEs undergoing digital and green transformation. By establishing a robust framework for tracking progress, gathering feedback, and driving iterative improvement, the UAM empowers organizations to build a culture of excellence and innovation that can withstand the challenges and opportunities of the future.

Through a range of tools and support services, the UAM helps SMEs develop the skills, capabilities, and mindset needed to embrace change, learn from experience, and create value for all stakeholders. By taking a data-driven, agile, and stakeholder-centric approach to continuous improvement, SMEs can not only enhance their own competitiveness and resilience but also contribute to a more sustainable and prosperous future for all.

F. Annex 1 – UAM Value Proposition Canvas

In the journey towards digital and sustainable transformation, manufacturing SMEs face a unique set of challenges and opportunities. To effectively support these businesses in their transition, it is crucial to develop a tool that comprehensively addresses their specific needs and pain points. The UAM aims to do just that, and the Value Proposition Canvas serves as a framework to ensure that the UAM is well-aligned with the requirements and aspirations of manufacturing SMEs.

At the heart of the Value Proposition Canvas lies the customer segment, which, in this case, encompasses manufacturing SMEs across various sectors, including Electronics & Software Products, Food & Beverage Products, Pharmaceutical & Chemical Products, Metal & Metal Products, Plastics & Rubber Products, Machinery & Equipment, and Building Materials & Furniture. Understanding the diverse nature of these businesses is the first step in crafting a value proposition that resonates with their specific contexts and challenges.

The next key component of the canvas is the customer jobs, which outline the main tasks and objectives that manufacturing SMEs aim to accomplish in their digital and green transformation journey. These jobs range from assessing their current readiness for transformation and identifying potential barriers and facilitators, to developing strategic action plans, complying with regulatory requirements, improving operational efficiency, enhancing competitiveness, and achieving sustainability goals. By clearly defining these jobs, the UAM can position itself as a comprehensive solution that helps SMEs navigate the complexities of the transformation process.

However, in pursuing these jobs, manufacturing SMEs often encounter various pains or challenges that hinder their progress. Financial constraints emerge as a significant barrier, as many SMEs struggle to allocate sufficient resources to invest in new technologies and green initiatives. The lack of in-house expertise and skills in digital and green technologies also poses a challenge, making it difficult for SMEs to identify and implement the most suitable solutions for their needs.

Cultural resistance to change within the organization can further complicate the transformation process, as employees may be hesitant to embrace new ways of working and adopt unfamiliar technologies. Navigating the complex and ever-changing regulatory landscape also proves to be a pain point for many SMEs, as they strive to ensure compliance with industry standards and environmental regulations.

Supply chain issues, such as logistical challenges and material availability, can disrupt the smooth implementation of digital and green initiatives. Technical challenges, including the integration and maintenance of new technologies, also pose significant hurdles for SMEs, particularly those with limited IT resources and expertise. Finally, high energy costs can strain SMEs' financial resources and hinder their ability to invest in sustainable practices and technologies. Despite these pains, manufacturing SMEs stand to gain significant benefits from successfully undertaking digital and green transformations. The UAM aims to create value for these businesses by offering a range of products and services that directly address their needs and alleviate their pain points.

Comprehensive assessment tools enable SMEs to evaluate their current digital and green readiness, providing a clear starting point for their transformation journey. Customized training programs help bridge the skills gap and equip employees with the necessary knowledge to effectively adopt and utilize new technologies and sustainable practices. Expert consulting services offer strategic guidance and support, helping SMEs navigate the complexities of planning and implementing digital and green initiatives.

Integrated technology platforms streamline the management of digital and green initiatives, providing SMEs with a centralized system to monitor progress, track performance, and make data-driven decisions.

Benchmarking tools allow businesses to compare their performance against industry standards, identifying areas for improvement and setting realistic targets. Access to funding and financial assistance programs helps alleviate the financial burdens associated with transformation, enabling SMEs to invest in the necessary technologies and resources.

Collaborative networks foster knowledge sharing and best practice exchange among manufacturing SMEs, creating opportunities for peer learning, collaboration, and collective problem-solving. By participating in these networks, SMEs can tap into a wealth of expertise and insights, accelerating their transformation journey and avoiding common pitfalls.

The UAM's value proposition extends beyond merely offering products and services; it also focuses on creating gain creators and pain relievers that directly address the needs and challenges of manufacturing SMEs. Gain creators are the positive outcomes and benefits that SMEs can expect from engaging with the UAM.

Operational efficiency is a key gain creator, as the UAM provides tools and strategies to streamline operations, reduce waste, and optimize resource utilization. Cost reduction is another significant benefit, as the UAM helps SMEs identify areas where digital and green technologies can drive cost savings, such as energy consumption, material usage, and labor productivity. By supporting the development of innovative practices and maintaining a competitive edge, the UAM enables SMEs to differentiate themselves in the market and stay ahead of the curve.

Regulatory compliance is a critical gain creator, as the UAM offers guidance and support to help SMEs meet the complex and evolving regulatory requirements in their industry. By achieving compliance, SMEs can avoid costly penalties and reputational damage, while also positioning themselves as responsible and sustainable businesses. The UAM also helps SMEs maximize their sustainability impact by providing guidance on implementing environmentally friendly practices, reducing carbon footprint, and contributing to the circular economy.

On the other hand, pain relievers are the ways in which the UAM directly addresses the challenges and obstacles faced by manufacturing SMEs. Financial assistance, through access to funding and support programs, helps alleviate the financial constraints that often hinder SMEs' ability to invest in digital and green initiatives. Expert consulting services provide the necessary guidance and support to navigate technical and regulatory challenges, filling the knowledge gap and enabling SMEs to make informed decisions.

Customized training and development programs address the lack of in-house expertise and skills, empowering employees to effectively adopt and utilize new technologies and sustainable practices. Change management strategies help overcome cultural resistance to change, fostering a supportive and adaptable organizational culture that embraces transformation. Ongoing technical support ensures that SMEs have access to the necessary assistance and resources to successfully integrate and maintain new technologies, minimizing disruptions and maximizing the benefits of digital and green initiatives.

Finally, supply chain optimization tools and strategies help SMEs navigate logistical challenges, improve material availability, and build resilient and sustainable supply chains. By addressing these pain points, the UAM enables manufacturing SMEs to overcome the barriers to transformation and unlock the full potential of digital and green technologies.

The Value Proposition Canvas provides a clear and structured framework for understanding the needs, challenges, and aspirations of manufacturing SMEs in their digital and green transformation journey. By aligning the User Acceptance Model's products, services, gain creators, and pain relievers with the specific jobs, pains, and gains of these businesses, the canvas ensures that the UAM delivers tangible value and supports SMEs in achieving their transformation goals. The visual representation of the Value Proposition

Canvas further reinforces the alignment between the UAM and manufacturing SMEs' needs. By placing the customer segment at the center and outlining their jobs, pains, and gains, the canvas highlights the key areas where the UAM can make a significant impact. The surrounding sections, detailing the UAM's value proposition, gain creators, and pain relievers, demonstrate how the model directly addresses the specific requirements and challenges faced by SMEs.

The Value Proposition Canvas serves as a powerful tool for ensuring that the User Acceptance Model is well-positioned to support manufacturing SMEs in their digital and sustainable transformation efforts. By understanding the unique needs, challenges, and goals of these businesses, the UAM can offer a comprehensive and tailored solution that drives operational efficiency, cost savings, regulatory compliance, and sustainability impact. As manufacturing SMEs continue to navigate the complexities of the digital and green landscape, the User Acceptance Model, guided by the insights provided by the Value Proposition Canvas, will play a crucial role in supporting their transformation journey. By delivering the necessary tools, guidance, and support, the UAM will empower SMEs to overcome barriers, unlock new opportunities, and thrive in an increasingly competitive and sustainable business environment.

Visual Representation of the Value Proposition Canvas

| Customer Segment
Manufacturing SMEs |

| Customer Jobs |
| - Assess readiness for digital and green transformation |
| - Identify barriers and facilitators |
| - Develop strategic action plans |
| - Comply with regulations |
| - Improve efficiency and reduce costs |
| - Enhance competitiveness |
| - Achieve sustainability goals |

Gains	Pains
- Increased efficiency	- Financial constraints
- Cost savings	- Lack of expertise
- Enhanced competitiveness	- Cultural resistance
- Regulatory compliance	- Regulatory complexity
- Sustainability	- Supply chain issues
- Innovation	- Technical challenges
- Market recognition	- High energy costs

| Value Proposition |
| - Assessment Tools |
| - Training Programs |
| - Consulting Services |
| - Technology Platforms |
| - Benchmarking Tools |
| - Financial Support |
| - Collaborative Networks |

Gain Creators	Pain Relievers
- Operational efficiency	- Financial assistance
- Cost reduction	- Expert consulting
- Innovation and competitiveness	- Training and development

- Regulatory compliance	- Change management
- Sustainability impact	- Technical support
	- Supply chain optimization

The canvas includes all essential elements of the UAM's value proposition, ensuring that it addresses the specific needs, challenges, and goals of manufacturing SMEs aiming for digital and sustainable transformations.

G. Annex 2 – User Acceptance Model with Instructions

Developed as part of the GREENE 4.0 project, the UAM is a comprehensive framework designed to help manufacturing SMEs assess their current digital and green maturity, identify key areas for improvement, and identify a course for successful transition.

The model covers a wide range of business categories and processes, from core manufacturing operations to support functions like market and business processes, manufacturing operations processes, organizational and managerial processes, training and skills development processes, investment process, government, informational processes. For each process within these categories, the UAM uses a four-point maturity scale for both digital and green aspects:

Basic - Limited digital/green initiatives enforced and low digital literacy/sustainability awareness.
Explorative - Strong ambition/ability to explore digital/green opportunities but unsure where to start.
Developing - Some digital/green initiatives implemented and moderate digital literacy/sustainability awareness.
Advanced - Digital/green initiatives extensively leveraged and embedded in core operations.

This scale allows companies to clearly see where they stand in each area and what the next steps might be for improvement. A unique feature of the UAM is that it assesses each process from both a digital and a green perspective. This dual approach recognizes that digital transformation and sustainability are often interlinked and can mutually reinforce each other.

Another important aspect is that each business process comprises dedicated metrics for supporting the empirical assessment of the maturity level of each process. This comprehensive approach ensures that no critical area of your business is overlooked in the transition processes.

- For each process, the UAM uses a four-point maturity scale ranging from "Basic" to "Advanced". This allows you to clearly see where you stand and what the next steps for improvement might be.
- Uniquely, the UAM assesses each process from both a digital and a green perspective, recognizing that these transitions are often interlinked and can mutually reinforce each other

The model includes a detailed questionnaire and accompanying guidelines (metrics and support questions) to help you thoroughly assess your current practices and potential for improvement.

After the initial assessment, the UAM incorporates a feedback session to help you reflect on your scores and start planning your next steps.
Based on your assessment results, the UAM matches with support GREENE 4.0 services and tools to support each manufacturing
company develop concrete action plans for improvement.

By using the UAM, a manufacturing company can gain a clear picture of where the company stands
in its digital and green journey, identify priority areas for improvement, and develop a roadmap for moving forward.