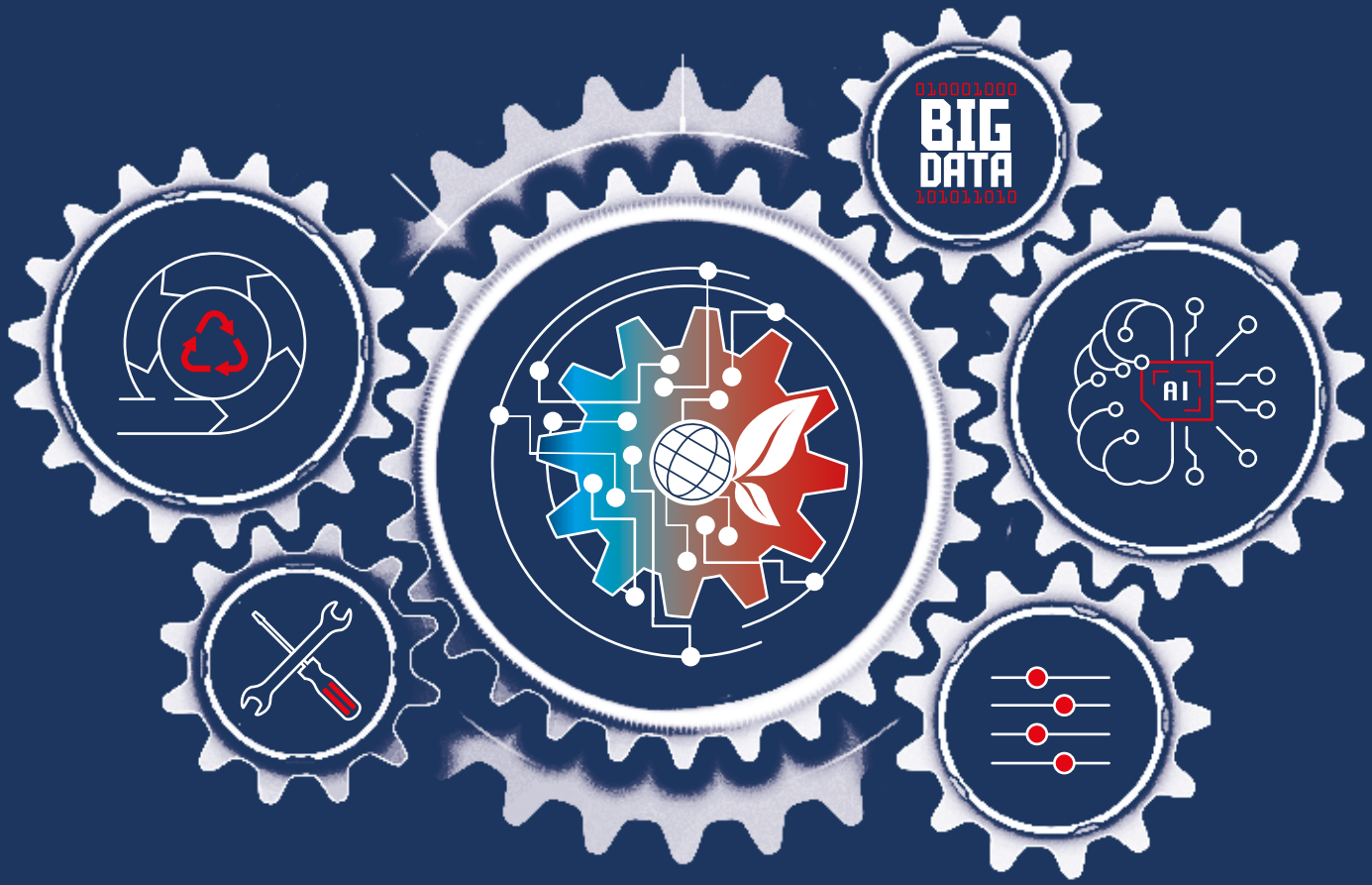
THE 2023 WORLD MANUFACTURING REPORT

NEW BUSINESS MODELS FOR THE MANUFACTURING OF THE FUTURE



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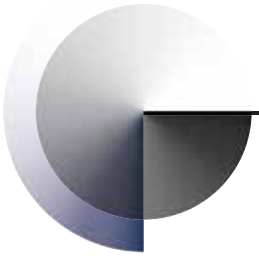

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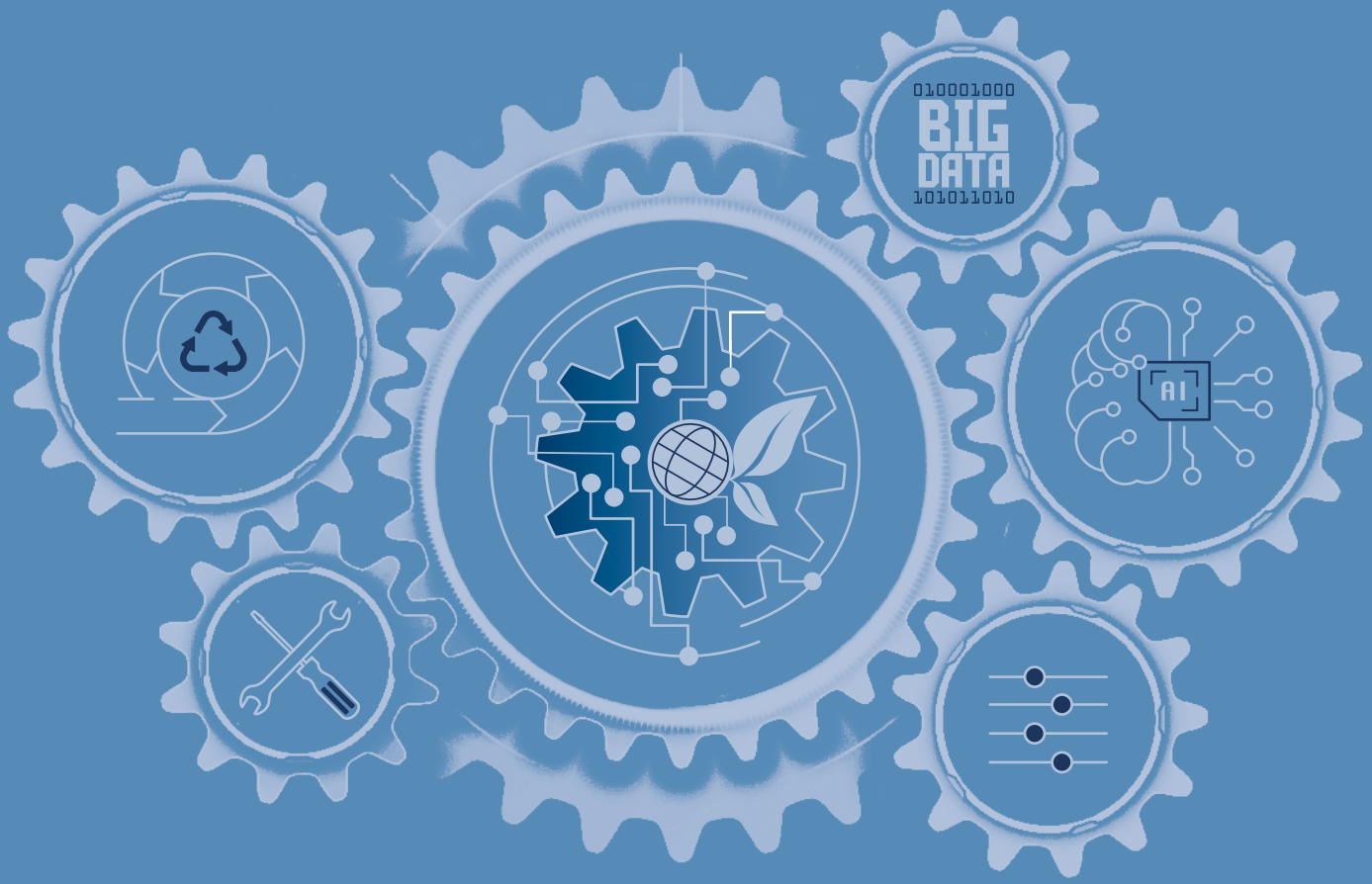
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Foreword

Dear Readers,

With the mission to spread industrial culture worldwide, the World Manufacturing Foundation (WMF), organises several activities, among which the World Manufacturing Forum, where this Report is presented and discussed by the speakers from industry and academia. The WMF can be considered a dynamic platform where representatives of countries, organisations, and institutions can exchange views and share their visions, initiatives, and current activities addressing the evolving paradigms of manufacturing.

The Editorial Board of the *World Manufacturing Report*, composed of a selected group of experts, harnesses its expertise and knowledge for the elaboration of the Report itself, which is also enriched by feedback and suggestions from the international Advisory Board. The annual topic of the Report is aligned with that selected for the Forum. In this regard, the past Reports are worth mentioning. The first *World Manufacturing Forum Report: Recommendations for the Future of Manufacturing*, published in 2018, presented our vision for the future of manufacturing. The 2019 *World Manufacturing Forum Report: Skills for the Future of Manufacturing*, analysed the skills gaps phenomenon in the sector. The 2020 *World Manufacturing Report: Manufacturing in the Age of Artificial Intelligence* provided insights on the successful and sound adoption of artificial intelligence in manufacturing. The 2021 *World Manufacturing Report: Digitally Enabled Circular Manufacturing* highlighted the key potentialities of the technological advancements in undertaking a circular transition. Last year, the 2022 *World Manufacturing Report: Redesigning Supply Chains in the New Era of Manufacturing* analysed the key global megatrends and their implications for manufacturing companies.
This year's Report will focus on the *New Business Models for the Manufacturing of the Future*. The Report analyses the leading-edge trends driving innovation in manufacturing business models while exploiting digital advancements to address economic, ecological and social needs. As tradition dictates, the *World Manufacturing Report* proposes 10 Key Recommendations. These recommendations represent suggestions for the manufacturing community and society at large to advocate the undertaking of actions to move towards the creation of innovative and sustainable business models, embarking on an ecological and digital transformation.
The World Manufacturing Foundation, through the *World Manufacturing Report*, commits to producing high-quality and non-partisan content on major themes and issues in manufacturing. We hope that this whitepaper will be useful for policymakers, for academia, and for society at large, to promote the redesigning of business models fostering the ecological transition relying on the current technological advancement.

We thank the *2023 World Manufacturing Report* Editorial Team and International Advisory Board for their valuable contribution.

Prof. Marco Taisch
Scientific Chairman
World Manufacturing Foundation

Prof. David Romero
Scientific Vice-Chairman
World Manufacturing Foundation

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2023

NEW BUSINESS MODELS FOR THE MANUFACTURING OF THE FUTURE

Index

Executive Summary

The 2023 *World Manufacturing Report: New Business Models for the Manufacturing of the Future* aims to depict the key trends that are characterising the current economy and thus, indirectly, the manufacturing sector. To address this purpose, a deep analysis has been conducted on both scientific and grey literature involving an international panel of experts in the field. As a result, the identified trends suggested the establishment of six potential business models by manufacturing companies. Through the analysis of the six business models, 10 Key Recommendations have been delineated to suggest how to be competitive in this changed economy while covering the nine building blocks of the business models.

In the ever-evolving global manufacturing business landscape, manufacturing firms stand at a crucial juncture. To thrive in the face of technological advancements, changing consumer demands, and environmental considerations, manufacturers must individually and collectively embrace business model innovation. It is time to reimagine and reshape the way the manufacturing sector operates to ensure sustainable growth and resilience in the long run.

Among the key economic trends that the manufacturing sector is experiencing, it is worth mentioning digital transformation. This transformation is leading to a widespread use of data and artificial intelligence algorithms supporting the decision-making process in delineating the value propositions of manufacturing companies. In this changed context, mass customisation is also spreading as a means of addressing customer needs. In the same vein, servitisation is gaining momentum in manufacturing companies, supported by the increase in circularity principles which are helping to outline sustainability-oriented business models.

Finally, the 10 Key Recommendations proposed have the intention of suggesting actions to be undertaken to face the trends that are currently characterising the manufacturing sector. More precisely, the suggestions cover all nine building blocks of business models. Among them, it is recommended that customer-centric innovation be embraced, by relying on both sustainability principles and mass customisation to define the value proposition. It is also suggested that new sales channels be created, customer relationships be improved by expanding partnerships beyond today's value chains, balancing key resources and exploiting AI and data analytics for new revenue streams.

Project Methodology

The World Manufacturing Report is an annual whitepaper discussing key trends in the manufacturing sector. This year the focus has been directed towards innovative and sustainable business models that can take advantage of the rapid technological advancement to face disruptive events impacting on manufacturing companies as well as on the entire society.

The *World Manufacturing Report* was developed by a heterogeneous Editorial Team, in terms of gender and country, and supported by the international Advisory Board composed of people from prestigious universities and organisations. The Report was built upon the integration of sources retrieved from both scientific and grey literature through an extensive review of the state of the art. This process led to the analysis of the main changes delineating the key trends driving innovation in manufacturing companies' business models and related key implications.

Finally, the *World Manufacturing Report*, as for the past three years (2020-2022), includes a set of case studies written by both scientific experts in the field and the Young Manufacturing Leaders. The latter were selected as winners from among the Young Manufacturing Leaders participants in a dedicated call for papers. The Young Manufacturing Leaders project, co-funded by the European Union under the EIT Manufacturing Initiative, is a global network of students and young workers interested in a career in the manufacturing sector.

1

Manufacturing Business Model Innovation

What is a manufacturing business model?

In simple words, a manufacturing business model refers to the way a manufacturer creates value and structures its operations to transform raw materials and components into finished products through a series of design, production, and logistics processes to create and deliver value to its customers as well as capture value for itself and its stakeholders.

Business models are integral to a manufacturer's success and competitive edge as they provide a roadmap for creating value, generating revenue, managing costs, and adapting to a dynamic business environment[1]. Manufacturing firms that strategically design and execute innovative business models are better positioned for long-term success[2 3].

A generic manufacturing business model can be described in terms of nine key building blocks[4] that interact to configure different organisational resources, activities, and partners to create and deliver products and services to one or more customer segments through the proper channels and relations within a reasonable cost and gaining acceptable revenue and profits. These building blocks include (see Figure 1):

Customer segments that represent the different groups of customers a manufacturing business serves with its products and services. These customer groups could include industrial clients, wholesalers, retailers, or end-consumers. Identifying and understanding the specific needs and characteristics of each of these customer groups is crucial for tailoring the manufacturer's value propositions accordingly and for effectively configuring the required resources, activities, and partners for the design, manufacturing, and delivery of such value propositions through the proper channels.

The **value proposition** that stands for the unique value (benefits) a manufacturing business can offer to its customers in terms of new product designs and features, superior quality and performance, mass customisation or personalisation options, or other value-added factors such as complementary services that set a manufacturer's products apart from those of its competitors.

Channels that determine the most effective ways to reach and sell to customers. These channels might involve direct sales, distribution through retailers, e-commerce platforms, or partnerships with other businesses. Channels also consider the supply chain and logistics aspects integral for delivering complete and timely product orders.

Customer relationships that outline how a manufacturing business will engage with its customers. This could include customer support, warranty services, and other post-sales interactions during a product's middle- and end-of-life as well as regular communications to understand and meet evolving customer needs.

Revenue streams that specify the sources of revenue for the manufacturing business. This could include product sales, maintenance contracts, licensing fees, or any other ancillary services that can contribute to the income streams.

Key resources that account for the critical resources and assets required to operate a manufacturing business from raw materials to production facilities and equipment to skilled labour.

Key activities that define the design, engineering, and manufacturing processes needed to conceptualise and develop a product.

Key partners that can enhance the manufacturing capabilities of the business or provide access to key resources and assets. These alliances might include suppliers, distributors, or joint ventures.

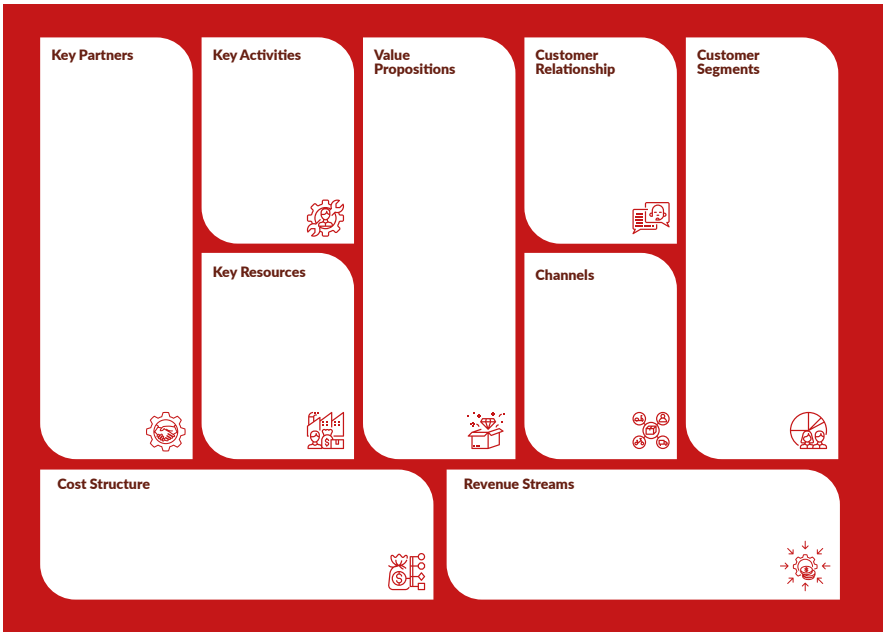
Cost structure that outlines the major costs associated with running a manufacturing business, including raw materials, labour, facilities, distribution, and overhead costs.

What is manufacturing business model innovation?

Manufacturing business model innovation refers to the process of strategically reimagining and redesigning one or more of the nine building blocks of a manufacturing firm's business model and/or the architecture linking these building blocks by looking at innovative ways of creating, delivering, and capturing new forms of value, enhancing competitiveness, and adapting to changing market and consumer dynamics[5 6]. It involves a systematic and radical

Figure 1

The Business Model Canvas



departure from traditional manufacturing approaches, encompassing significant changes in how a manufacturer designs, produces, sells, and supports its products along their lifecycles.

Key areas for manufacturing business model innovation related to the nine building blocks of a generic manufacturing business model include but are not limited to:

New customer-centricity approaches place a strong emphasis on understanding and meeting the targeted customer segments' needs and engaging customers in value co-creation and co-innovation activities to ensure that the offered products and services align with their expectations.

New value propositions focus on creating new mass-customised or personalised sustainable products, enhancing existing ones with new sustainable and smart features, or providing additional services to these to better meet evolving customer needs.

New sales channels such as online marketplaces and social media channels sell directly to consumers and bypass traditional retail channels, thus leading to better shopping experiences.

New customer relationships prioritise the customer through distinctive loyalty programmes, special promotions, and unique shopping experiences, tailored with customer data insights, which demonstrate a deeper understanding of customer pains.

New revenue streams beyond selling physical products explore new recurring income sources based on the offering of services and solutions, for instance, maintenance, upgrades, and performance-based contracts as well as leveraging data monetisation opportunities.

New resources management practices based on the circular economy principles minimise the impact of finite resource consumption and create truly sustainable business models and value propositions.

New activities optimisation efforts enhance efficiency, boost productivity, minimise waste, reduce costs, and improve product quality.

New partnership schemes based on collaborations with other manufacturers, suppliers, or even competitors create synergies and unlock new value propositions by integrating complementary products and/or services.

New cost structures analyse and better manage the various costs incurred in the design, manufacturing, and delivery of products and services to enhance profitability.

Why does manufacturing business model innovation matter?

"Today's competition among (manufacturing) enterprises is no longer between products, but between business models." Peter Drucker

According to EY[7], manufacturers seeking a competitive edge can no longer depend on product-centric innovations. They must develop business model innovations to create, deliver, and capture value in new ways. For decades, manufacturing business models have largely focused on

incremental growth through product improvement or market expansion. However, stagnating economic growth, global market disruptions, and diminishing returns from incremental product and process improvements are challenging manufacturers. In response, manufacturers need to broaden their innovation efforts beyond the customer segments and value proposition building blocks of their business models. Not doing so can create opportunities for competitors willing to capitalise on evolving customer needs and market dynamics.

Manufacturing business model innovations offer an important opportunity for manufacturing businesses to transform and upgrade their value propositions and operating models to adopt the sustainable business models being demanded by our planet, growing environmentally conscious consumers, and increasing environmental regulations[8].

Manufacturing business model innovations are a solid way to create value for customers and stakeholders by discovering new customer needs, new customer segments, and new profit-making methods[9]. Manufacturing business model innovations allow manufacturers to acquire and realign their existing assets and capabilities to better create and deliver their future value propositions[10].

Key reasons why manufacturing business model innovation matters include[11]:

Competitive advantage as innovation in a manufacturing firm's business model differentiates the business from its competitors by offering unique products or services, or better customer experiences.

Cost efficiency and operational excellence as business model innovation often involves finding new ways to optimise processes, reduce costs, and enhance operational efficiency. This can lead to cost savings in manufacturing processes, supply chain management, and overall operations, making the manufacturing business more financially sustainable.

Adaptation to technological advances facilitates and enables a manufacturing business to innovate its production processes and stay relevant in the market.

Flexibility and responsiveness allow a manufacturing business to deal with changes in market conditions, customer preferences, and regulatory requirements.

Customer-centricity approaches for innovating in the offering of value propositions based on mass-customised and/or personalised products, efficient after-sales services, and new distribution channels that better serve the needs of customers.

Sustainability and environmental considerations will push manufacturing businesses towards more sustainable and innovative practices for reducing waste, using eco-friendly materials, and adopting energy-efficient processes.

New income sources will open new, innovative avenues for generating revenue by introducing complementary products or services, entering new markets, or establishing strategic partnerships that create additional sources of income.

Risk mitigation as diversifying or differentiating the business model of a manufacturing firm through innovation can help mitigate risks associated with economic downturns, changes in consumer behaviour, or disruptions in the supply chain.

Talent attraction and retention since a forward-thinking and innovative business model can make a manufacturing firm more attractive to top talent.

Market Expansion as business model innovation can offer differentiated strategies for entering new markets, adapting to diverse cultural and regulatory environments, and effectively managing international supply chains.

In summary, manufacturing business model innovation is vital for manufacturing businesses to stay competitive, adapt to changing environments, and create sustainable growth in the dynamic landscape of the sector. It will allow manufacturing firms to align with market trends, technological advancements, and customer expectations, positioning them for long-term success.

How does manufacturing business model innovation impact the sector?

Manufacturing business model innovation can have a profound influence on the sector by bringing about positive changes in various aspects such as[12 13]:

Enhanced customer experience by easing customers' journeys from ordering to post-sale support and feedback mechanisms.

Customisation and flexibility by offering mass-customised and/or personalised products or quickly adapting production processes in response to market changes.

Efficiency and productivity improvement through the adoption of new technologies and innovative processes can lead to significant improvements in efficiency and productivity.

Cost reduction by optimising the supply chain, streamlining processes, or finding more cost-effective materials.

Supply chain optimisation through the integration of digital technologies for real-time monitoring, predictive maintenance, and demand forecasting, leading to better inventory management and reduced lead times.
Sustainable practices in raw materials, energy and water usage, and waste reduction to meet the growing demand for sustainable products.
Digital transformation through the integration of digital technologies, such as the Industrial Internet of Things (IIoT), big data analytics, and artificial intelligence can transform traditional manufacturing processes.
Servitisation by shifting manufacturers from a product-centric model to a service-oriented model that involves not just selling products but offering additional services, such as maintenance, updates, or performance monitoring. This can provide a steady revenue stream and build long-term customer relationships.
Collaborative ecosystems where resources, knowledge, and capabilities can be shared to foster innovation and mutual growth.
Rapid prototyping embraces an iterative development to bring new products faster to the market in response to changing customer preferences and market dynamics.
Risk management as a common practice in innovation efforts to diversify product offerings, markets, or suppliers to reduce vulnerability to disruptions.
In summary, manufacturing business model innovation can lead to a more agile, efficient, and sustainable sector by embracing new digital technologies and rethinking traditional manufacturing in an ever-evolving global market.

What are the challenges of manufacturing business model innovation?

While manufacturing business model innovation can bring about positive changes as discussed, it also comes with its set of challenges. Here are some common hurdles that manufacturing firms may face when attempting to innovate their business models[14 15]:
Resistance to change is one of the primary challenges to manufacturing business model innovation as employees may be hesitant to adopt new technologies or ways of working.
High initial costs that come with the implementation of new technologies or processes that can require a significant upfront investment.
Integration with legacy systems as new technologies may not be easily compatible.
Skills gaps as the adoption of advanced technologies may require new skill sets not available in the workforce.
Data security concerns as production equipment becomes more connected through the Internet of Things (IoT) and other digital technologies, there are increased concerns about cyber threats.
Regulatory compliance as new business models may require manufacturing firms to navigate complex regulatory landscapes, which can slow down the pace of innovation.
Uncertain return on investment (ROI) as manufacturing firms may hesitate to invest in new technologies without a clear understanding of the long-term benefits and financial returns.
Cultural shift towards a true culture of innovation can be difficult since it requires not only changes in processes and technologies but also a shift in the organisational mindset, embracing experimentation, learning from failures, and continuous improvement.
Lack of standardisation can complicate the adoption process of new technologies.
Market acceptance when introducing new products or services through innovative business models may face challenges in gaining customers' and partners' acceptance.
Long implementation timelines as significant changes in business models can take time.
Overcoming these challenges requires strategic planning, effective change management, and a commitment to fostering a culture of innovation within a manufacturing firm.

Call for Action for manufacturers in regard to manufacturing business model innovation

In the ever-evolving global manufacturing business landscape, manufacturing firms stand at a crucial juncture. To thrive in the face of technological advancements, changing consumer demands, and environmental considerations, manufacturers must individually and collectively embrace business model innovation. It is time to reimagine and reshape the way the manufacturing sector operates to ensure sustainable growth and resilience in the long run.

This year's World Manufacturing Report analyses different business model innovation paths for manufacturing firms oriented towards digital, data-driven, AI-based, mass-customisation, servitised, and circular business models under the light of the digital economy. It aims to present relevant facts and figures and business model archetypes to motivate manufacturers to innovate their business models.

Global Competition is Changing: Manufacturing Business Models Should Too

Manufacturing Business Model Innovation Trends

Digital economy: from a physical economy to a digital economy

The digital economy is transforming manufacturing

The concept of the digital economy encompasses the advancements offered by digital technologies to society. It originates from previous information and knowledge-based economies, where increased information availability and human knowledge contributed to economic growth. However, it distinguishes itself from these preceding economic eras by intensively utilising at least four base digital technologies: Internet of Things (IoT), Cloud computing, Big Data, and Analytics (e.g. Business Intelligence and Artificial Intelligence)[16].

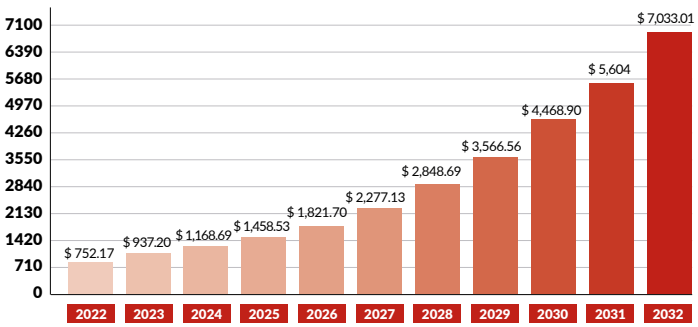
These technologies can significantly enhance the intelligence and autonomy of systems that operate machinery, equipment, and final products. By harnessing these cutting-edge technologies, companies are effectively narrowing the gap between physical and virtual environments, giving rise to cyber-physical systems that rely on these fundamental digital tools. In this context, the digital transformation represents the outcome of the digital economy, marking the progress achieved by implementing these digital technologies to advance cyber-physical systems.

The results of this transformation are indeed remarkable, with the global digital transformation market size estimated at USD 752.17 billion in 2022 and projected to exceed USD 7,033.01 billion by 2032, experiencing significant growth at an impressive Compound Annual Growth Rate of 25.1% from 2023 to 2032[17] (Figure 2).

Figure 2

Trends in the digital transformation market worldwide

(Source: Precedence 2023)

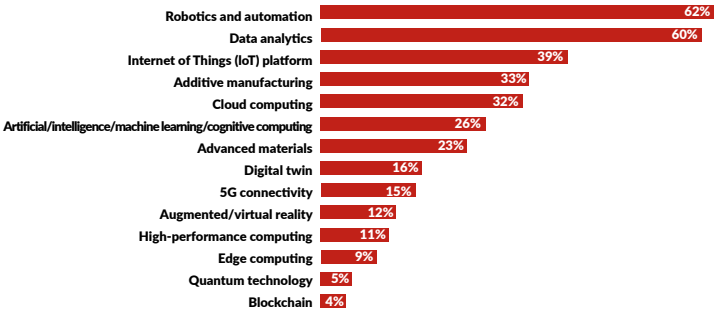


Furthermore, these technologies pave the way for integrating new technologies such as additive manufacturing, advanced robotics, digital twins, and an array of digital solutions for various business operations. In this sense, manufacturing companies have directed their investments towards various digital solutions to enhance their operations, as illustrated in a recent report by Deloitte[18] highlighting the most heavily invested technologies within the digital economy (Figure 3). Estimations point out that today's market size (2023) for digital transformation in manufacturing worldwide is around USD 307.87 billion, while the projections for the next five years suggest that it will grow to USD 733.75 billion[19].

Figure 3

Focus on current investments in manufacturing technologies

(Source: Deloitte 2023)



The impressive growth of such investments in manufacturing points out how the digital economy is transforming manufacturing. Such transformations can be witnessed in front- and back-end manufacturing activities. In the front-end activities, new solutions are being offered to the market. Smart connected products, new digital services that complement product sales, and new forms of product commercialisation such as product-as-a-service are examples of this front-end transformation pushed by implementing digital technologies. As a result, the manufacturing focus is not only on physical products, but also digital solutions related to such products[20]. On the other hand, investments in digital transformation are also transforming back-end activities, i.e. the operational manufacturing activities necessary to provide products and services. This includes implementing technologies to achieve more intelligent manufacturing systems, using digital tools to support workers and provide

upskilling or reskilling in front of their new necessary capabilities, or better integrating suppliers and external business partners by sharing real-time data across the companies' boundaries[21].

Digital business model example

An illustrative case of how manufacturing companies are transforming front- and back-end activities is that of WEG Motors, as the company is investing significantly in digitalisation to become a leader in its market through the intense use of digital technologies. WEG is a Brazilian multinational manufacturer specialising in industrial electric systems, including engines, transformers, and industrial appliances. WEG has embraced the evolving digital economy, steering its traditional manufacturing business model towards a digital-centric approach, consequently positioning itself as Brazil's most digitally advanced industrial company. To achieve this transformation, the company established an ecosystem of digital providers and strategically acquired companies like BirminD, a start-up specialising in AI solutions. These initiatives empowered WEG to cultivate new digital competencies in Industrial IoT, cloud solutions, and artificial intelligence. This strategic shift culminated in the development of a novel product portfolio known as 'WEG digital solutions'[22], offering IoT and cloud-based solutions for monitoring and enhancing electric motors. Additionally, WEG harnessed AI solutions to analyse engine data, enabling them to simulate plant modifications[23]. Furthermore, the company made significant strides in digitising its internal operations within the manufacturing process. They pioneered by becoming one of the first industrial pilots to implement a private 5G network within their plant operations[24]. As a result of such efforts, WEG joined the top-20 ranking of electric motor manufacturers in the world and is one of the most profitable industrial companies in South America. This case exemplifies how embracing digital transformation can project a traditional manufacturing enterprise into a leadership position in the global digital economy landscape.

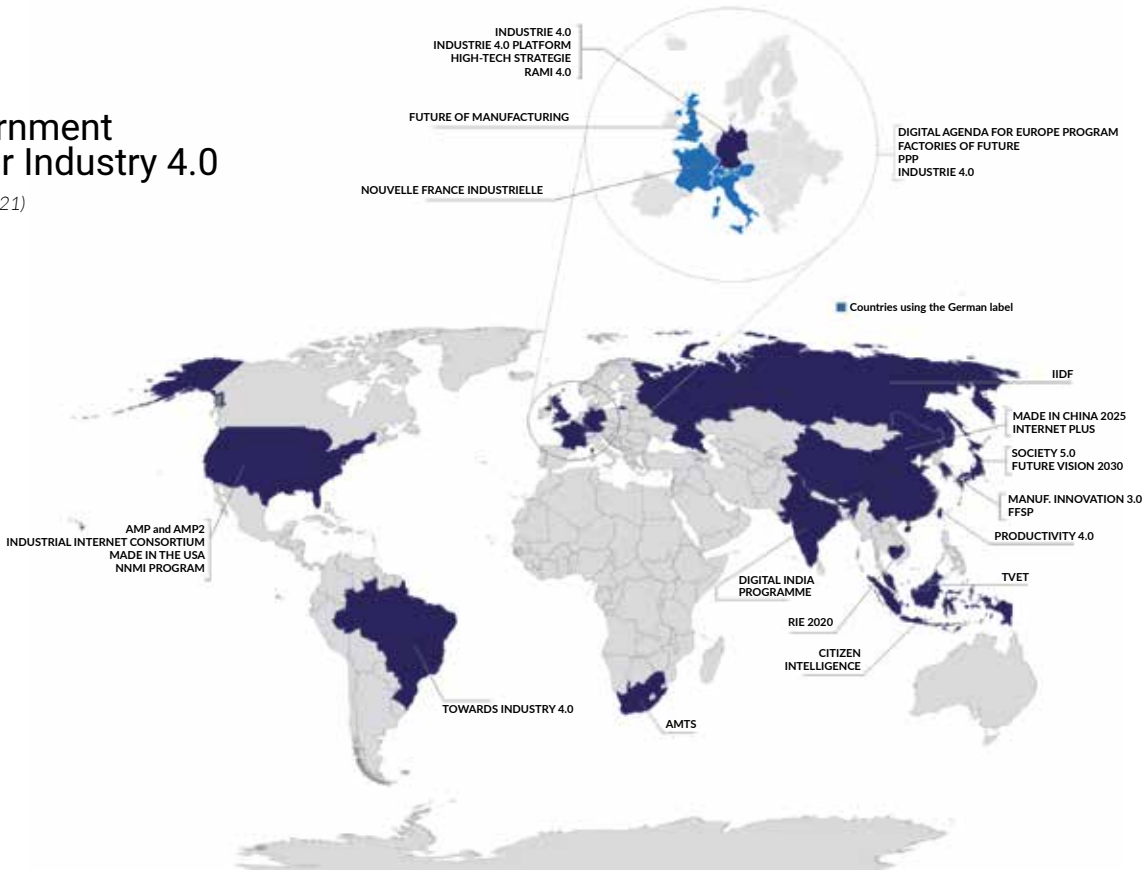
How nations are embracing the digital economy

The digital economy is not solely a technological phenomenon; it is the result of nationwide efforts undertaken by countries aiming to promote digital transformation as a core component of their industrial competitiveness. In the 2010s, leading nations such as the United States, Germany, China, and Japan initiated industrial policies and programmes to encourage the adoption of digital technologies in manufacturing[25]. Programmes like Industrie 4.0 (Germany), Made in China 2025 (China), and Manufacturing USA (United States), were designed to formulate various strategies to enhance the competitiveness of national manufacturing through the use of advanced digital technologies. These initial efforts quickly spread worldwide through national programmes aimed at embracing the digital economy, as illustrated in the study by Vope Rodrigues et al[26]. (see Figure 4).

Figure 4

Global government initiatives for Industry 4.0

(Source: Rodrigues et al. 2021)

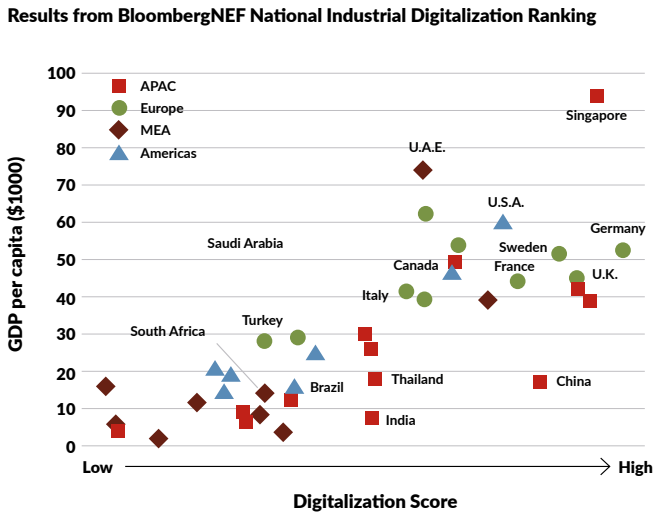


Such efforts have placed countries in significantly different positions regarding their digitalisation score compared to their GDP per capita, as demonstrated in BloombergNEF's study[27] (Figure 5). These findings highlight the existence of a virtuous cycle. National investments in digital transformation, primarily driven by government policies, influence the national industry, which results in increased prosperity.

Figure 5

National digitalization ranking

(Source: BloombergNEF 2019)



While the scale of investments varies from country to country, several key initiatives stand out. First, the most fundamental way to promote the digital economy is by allocating public resources to encourage technology adoption in industrial sectors or to support consumers in acquiring new digitally connected products, thus increasing demand (e.g. electric cars, digital services, etc.). This can take the form of direct funding for technology adoption or through taxation programmes. Second, governments actively promote research and development (R&D) and the commercial development of new digital technologies through innovation funds and testbed projects. Third, many countries focus on creating technology demonstrators, including laboratories and factory showcases, similar to those promoted by the German Industrie 4.0 platform. These types of initiatives are summarised below:

- **Direct Public Investments:** These investments aim to provide companies with resources for technology acquisition, facilitate accelerating start-ups working on digital technologies, and improve infrastructure elements such as 5G networks, data regulation, and standards. Their primary goal is to implement new technologies and enhance the manufacturing sector.

- **R&D Incentives:** These initiatives allocate resources and programmes to foster the development of testbed projects within research labs and companies. Their primary focus is advancing emerging technologies, supporting innovative projects, and encouraging patent creation.

- **Development of Technology Demonstrators:** These incentives are geared towards creating factory lighthouses, business showcases, and learning labs. They serve the purpose of cultivating business awareness and facilitating learning about new technologies.

One of the persistent challenges in promoting the digital economy revolves around engaging small and medium-sized enterprises (SMEs)[28]. Companies often perceive digital transformation technologies as requiring substantial investments, which can deter SMEs from showing interest or embracing them. While this perception holds some truth, as large software and hardware vendors develop many technology solutions for large companies, it is important to note that the landscape is evolving. There's a growing market for SMEs with an increasing number of tailored solutions, often delivered as service-oriented offerings[29]. Moreover, there are misconceptions within the digital economy about the necessity of significant investments. Many cost-effective solutions, such as plug-and-play IoT monitoring systems for small operations, have proven effective for SMEs[30]. Consequently, numerous government initiatives have emerged to support SMEs in bridging this digital gap in recent years. These initiatives have two purposes: creating market opportunities for technology providers catering to SMEs and raising technology awareness among SME entrepreneurs and business professionals. This concerted effort aims to foster greater engagement from these types of companies.

Another challenge for the digital economy and countries' policy programmes and initiatives is developing the new skills required for workers[31]. The introduction of digital technologies in manufacturing is creating knowledge and skills gaps. There is a need for more cognitive than manual tasks, as workers need to operate automated and digitalised equipment, producing a data-driven environment. Decision-making is changing to a data-driven base that tends to substitute the pure experience of the workers[32]. This changes the worker profile and even the job positions required in manufacturing. New demands for hardware and software programmers and operators of emerging technologies in manufacturing, like drones, cobots, and 3D printers, are growing worldwide. According to RAND Europe's report estimations[33], as much as USD 11.5 trillion of cumulative GDP growth is at risk in G20 countries if such digital skills gaps are not addressed soon. Thus, new training programmes aligned with digital skills are necessary to transform manufacturing. However, government initiatives are insufficient, and companies need to develop their training programmes to overcome the challenges of skills gaps.

Finally, a last challenge in the digital economy and for manufacturing firms is conciliating digital initiatives with the emerging 'green economy'. The United Nations Environment Programme[34] defines the green economy as a low-carbon, resource-efficient, and socially inclusive economy. This transition to the green economy will demand alignments in manufacturing activities to create sustainable production and consumption. In this sense, the digital economy should meet the green economy through the focus on using technologies not only for productivity but also for environmental and social benefits.

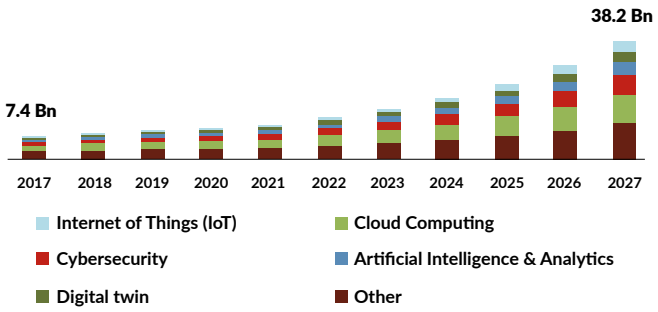
Digital technologies in manufacturing activities

The trend in this convergence between the digital and green economy is so strong that some studies indicate an expected market size of green digital technologies of USD 38.15 billion by 2027, rising at a market growth of 22.5% Compound Annual Growth Rate[35]. This growing trend is shown in Figure 6, which evidences the big opportunities to integrate digital technologies with sustainability.

Figure 6

Green technology and sustainability market size by technology

(Source: KBV research 2021)



Data economy: from data as a by-product to data as a product

Data economy context

The fourth industrial revolution is known for its huge impact on the transformation of manufacturing companies, which are integrating new technologies in their production and processes to improve their performance and resist the increasing market competition. One of the pivotal characteristics of the Industry 4.0 transformation is the capability of generating and collecting unprecedented quantities of data that companies can use to increase their knowledge of their processes, customers, and competitors.

Even though the use of data in companies is not something new in general, following the fourth industrial revolution and the possibility of collecting data through sources like sensors, web traffic, digital apps, or smart products, and share them easily for analysis increased the attention of manufacturing companies towards this topic and the possibility of consistently using data for business purposes.

The spread of data availability gave birth to the concept of the Data Economy, where companies use data as a central means of creating value. New, data-based value propositions are defined that aim at generating revenue streams based on the sale and use of data or the insights gathered from it. Such business models, centred upon data for revenue generation, are known as Data-Driven Business Models (DDBM).

Today, data is assuming even greater importance, becoming a vital and indispensable element for businesses. According to Brownlow et al. (2015)[36], data-driven approaches can enhance the company output and productivity in a range of 5 to 6 percent compared to non-data-driven ones. A survey of the Harvard Business Review further attributed data-driven organisations with an increase in product and service innovations, operational efficiency, customer retention and profitability, just to name a few[37].

Despite this, just collecting and storing or selling data is often not sufficient to generate business value. Companies need clear strategies to exploit and monetise data other than through simple sales. This is why DDBMs are closely linked to concepts like data-as-a-service, analytics-as-a-service or equipment-as-a-service based on the way data is wrapped around products, services or sold standalone to customers, in a raw or elaborated form.

Data-Driven Business Model definition

In terms of definition, Hartmann et al. (2014)[38] define the DDBM as "a business model that relies on data as a key resource", while Kühne et al. (2018)[39] explicitly reference the value proposition providing this definition of DDBM: "A data-driven business model relies on data as the main resource and data is necessarily required for the value proposition".
In this kind of business model, data drives company decisions at all levels (e.g. strategical, tactical, and operational) in a 'proactive' manner. Thus, data is not used as a 'reactive' instrument but contributes to anticipating trends and problems, allowing companies to make informed decisions able to maximise value while minimising negative effects. DDBMs are useful because they allow companies to get closer to customers, fostering tailor-made decisions in terms of products and services offered, aligned to the actual needs of the customers. In this sense, they foster the transition from a pure, product-based, transactional

relationship, to a relational one, where providers and customers become business partners with the common interest of maximising each other's value.

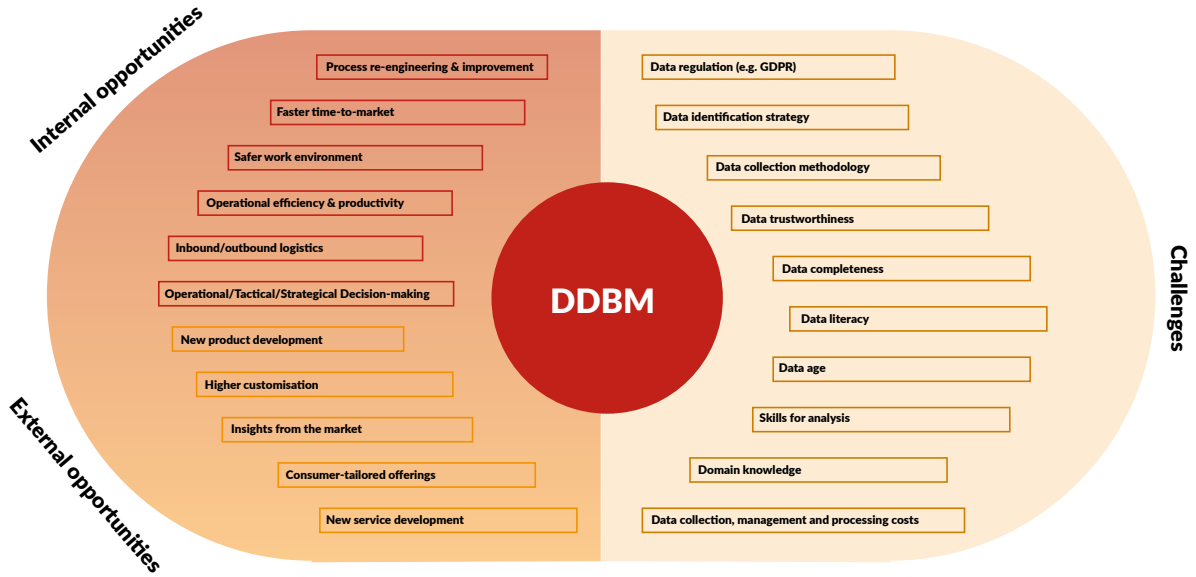
In summary, DDBMs are business models built around the concept of data as a central means of creating connections with the customers and mutually generating value (e.g. through promotion, pricing, sales, and delivery).

Data-Driven Business Model benefits

Companies can use data to introduce incremental improvements and/or optimise business processes and services. Also, data can be used to support the instantiation of new value propositions. In the following, internal and external opportunities will be discussed (see Figure 7).

Figure 7

Benefits and challenges in Data-Driven Business Models



Internal opportunities

Process improvement and operational efficiency are among the most pursued objectives for internal data utilisation. The collection and analysis of data on operational activities that characterise production processes could be used to study average execution times, deviations, critical stages, and misalignments between activities. By using such data in the correct way, internal processes could be re-engineered to reduce problems and waste (both time-related and cost-related) to improve performance and guarantee a faster response to the market, while increasing general efficiency and reducing execution costs. In other words, this would mean increasing the workers' morale, leading to higher productivity and satisfaction through a better and safer work environment.

Moreover, data can be used to improve the management of all the business processes associated with internal operations (e.g. inbound logistics) with improved coordination of the supply chain required for production. Data can also be used to make decisions at different horizon times, ranging from short-term, day-by-day, decisions (operational level) to long-term ones (strategical). Specifically, the level of aggregation to which data is used allows different use cases to be defined and provides the different actors with the granularity they need to make decisions.

External opportunities

DDBMs are not only oriented to generate internal improvements but also to allow companies to improve the offering marketed to customers, being that focused on one (or more) product(s) or service(s). The collection and analysis of data from the market and the customer(s) allows companies to delve into the habits and most important trends and/or gaps that must be addressed. Data-driven companies, by analysing data, have the possibility of customising their offerings based on the necessities of the single customer, allowing them to create a greater sense of intimacy and nurturing prolonged relationships, locking in the customers for longer periods while locking out competitors. Such customisation can be associated with a product (e.g. in terms of design and/or functionalities) or, more frequently, with the service offering associated with the product. For instance, a deeper knowledge of customer habits in terms of product usage, might favour the offering of specific training or consultancy on how to use products. In turn, this results in a higher competitive advantage in the market and an enhanced reputation, favouring the attraction of new customers.

By analysing aggregated customer data and data collected from other sources, companies might be able to identify new opportunities of which they may not have been aware before. For instance, new market segments, or common customisation requests could be isolated and used to launch new products or services on the market anticipating the competitors.

Typologies of users

According to Bulger et al. (2014)[40] three main organisational roles can be identified in DDBMs: *data users*, *data suppliers*, *and data facilitators*. These three typologies have different characteristics and scopes, but they all rely on data to make decisions and generate value.

Data users tend to use data (collected from customers or bought from third parties – i.e. *data suppliers*) and analyse them to make business decisions. These are either related to internal processes (e.g. production planning), network (e.g. supplier selection), portfolio (e.g. new/update product or service), and others. The main question to answer for data users is *"Which data are available? How can we create value from the data?"*

As the name suggests, Data suppliers are focused on generating and selling data to other actors. Data are sold, in a raw or aggregated form. Companies that are classified under the umbrella of *Data suppliers* are not only those who generate and sell data but also those that act as intermediaries collect data from multiple sources. For such companies, the main questions to answer are "What is the business value of data? Who is interested in the data? How can we gain certain data? How should the data be delivered?".

Finally, *Data facilitators* represent companies that support other companies in making the right use of data and generate value from the analyses. Companies provide the competencies to extract useful information and knowledge from collected (or bought) data. Offering data literacy or analytics-as-a-service helps others to become data-driven decision-makers. Questions to answer are: "Which information is needed? How is domain knowledge reflected in data?"

Typologies of data and potential challenges

While increasing amounts of data are generated, data users need to understand what typologies of data are available and who owns them. The ownership of data is, in fact, one of the pivotal themes of discussion for companies who want to become data-driven and make (internal) decisions or offer services based on data.

In general, *First-party* data are those directly collected from the customers. Such data can contain personal information that could be used to identify the customer and should be treated according to community regulations.

Second-party data are collected with the help of other companies (e.g. support from marketing vendors) through clear and shared methodologies and scopes. The ownership of such data is in a grey zone (the company that collected the data or the one that commissioned the collection?). Contractual agreements must be defined to regulate the ownership and business exploitation.

Then, *Third-party* data represent the last typology, where the data collection process is not always clear and, thus, data might have a lower level of trust compared to the first two types, depending on the company that performed the data collection. This kind of data might derive from web-scraping activities or other means of collection and processing. When buying such data, the users get results but not always details on sampling methods and other aspects.

The use of data-driven approaches and the construction of DDBMs can benefit companies of all sizes thanks to the possibility of defining new revenue streams and getting closer to the customers. **While DDBMs envision multiple benefits for companies embracing them, it must be clarified that some challenges must be addressed before marketing data-driven offerings.** Among these, three macro-categories can be identified: i) how to collect data, ii) how to manage and process data, iii) how to use data correctly. In fact, if these challenges are not addressed in the proper manner, companies are risking incurring losses instead of benefits.

Regarding data collection, companies must understand what data is necessary to collect and process, defining why they are important and what scope they serve. Without a clear purpose for collection, the risk is to collect and store non-useful data, generating avoidable costs for the company. Moreover, the lack of a purpose for data collection might result in the non-collection of critical typologies of data that might support, if well managed, processed and used, important business decisions at strategic, tactical, and operational levels. Linked to this, the theme of the trustworthiness of the data origin must be addressed. Companies must ensure that the instruments and tools used for data collection and transmission are reliable. Missing data or data wrongly sampled could favour misinterpretation of the real situation, forcing unfavourable business decisions. Another aspect that should be taken into account is if, and how, other companies decide to share data, both internally and externally. The access to specific typologies of data for collection might be critical to enable the delivery of the promised services. For instance, the unavailability of operational data might prevent the delivery of remote monitoring and predictive

maintenance services. Data sharing decisions are human-based and have a critical impact on the following processing and use phases.

Regarding data management and processing, companies must ensure that data are not decontextualised when merged or transferred from one place to another. Decontextualising data might lead to misuse and lead to a misunderstanding of their meaning, leading to incorrect decisions that might negatively affect the business. In addition, also the age of data must be considered. Old data might not be useful for making decisions for the future. Thus, it is always necessary to verify that data stored and processed are accurate enough to be used in support of business decisions. In addition, one of the pivotal requirements for companies which intend to embark on DDBM adoption and generate value through data, is the presence of personnel with technical skills who are able to make use of data in a proper way. If not present internally, companies must rely on partners providing such skills for data management and processing, able to synthetise data and present them in a form suited for decision-making support. It is also important that data analysts and data scientists working on data have domain knowledge or are in contact with employees who can provide directions on the underlying meaning of the data under analysis, so as to ensure the correct interpretation of data before their elaboration. While this might be a cost for the company, it is fundamental for the correctness of the analysis.

Regarding data usage, companies must address the problem of the cost of collecting, cleaning, managing, and analysing data to make decisions. Thus, companies must understand if the value created by the data is higher than the cost required for its collection, preparation, and use. In some cases, also at managerial level, coding skills might be helpful to understand how some results have been obtained or to perform additional analyses. At managerial level, domain knowledge is useful to understand how to extract value from data, give directions on model development and identify opportunities and threats after data processing. Also, managerial expertise helps in defining where additional useful data might be retrieved or purchased.

On a more general level, companies must take into account also political regulation on data collection and management established at national and international level. For instance, data management in the EU must be aligned with the requirements of the GDPR, while for other regions of the world, data management regulations are different. This is especially important when it comes to privacy and personal data issues. Thus, companies must ensure that data collection, management, processing, and usage are aligned with the regulations of the country in which they are operating with the DDBM.

Examples of Data-Driven Business Models

Among the most discussed services linked to DDBM and data analysis is predictive maintenance, which bases its selling proposition on the possibility of forecasting future failures and acting before breakdowns take place to reduce productivity losses and avoid prolonged stops. This kind of approach has several advantages, including reduced downtime of the machine (e.g. just the time required for fixing or adjustment of the problematic part), extended product lifecycle (e.g. anticipating failure to avoid critical damage to the whole product), reduced maintenance costs (e.g. few spare parts to use and/or components to substitute, scheduled interventions), improved safety (e.g. the works can use a reliable product and the risk for unexpected failures and injuries is reduced). All these benefits lead to higher productivity for the customers.

Frequently, predictive maintenance is associated with remote monitoring offerings, where the provider supports the product user in improving the performance of the product. As said, being strictly connected to predictive maintenance, the provider can warn the user about incoming problems and about the health status of the product. Travelling costs can be reduced, as well as the environmental impact of travel. Customer service is enhanced, since the provider is committed to helping the user to perform at their best and is available for support remotely and, when necessary, on site.
The following are some examples of manufacturing companies working with DDBMs. The exemplary cases listed will show how DDBMs can be applied to improve and address various areas of the manufacturing value chain, ranging from internal decisions to product and service improvement.

Siemens uses data to develop new products and services, optimise its manufacturing processes, and improve its customer relationships. For example, Siemens' IoT platform is used to help customers improve the energy efficiency of their buildings and factories.

Airbus uses digital twins of the aircrafts to improve the design as well as the production process. This results in reduced design time (thanks to simulation that allow the covering and comparing of different scenarios) as well as the optimisation of fuel consumption during flight.

Toyota enhances the application of the Toyota Production System (TPS) through the collection and analysis of data to minimise waste, enhance quality, and maximise efficiency.

Tesla uses data from its sensors and cameras to monitor the production process and identify improvement areas - for instance, to optimise the placement of robots on the assembly lines.

Rolls-Royce collects data from its engines in the field and uses it to monitor their behaviour and health status and, based on that, schedule customised maintenance plans.

Ford uses data-driven approaches to enhance its manufacturing processes and improve vehicle design. Not only that, but data collected from the field are used to provide customers with real-time diagnostics and maintenance alerts.

IBM acts as a data facilitator using AI and data analytics, supporting companies in developing cloud platforms, models, and algorithms to be used for predictive maintenance, quality control, and supply chain optimisation.

Procter & Gamble (P&G) uses data analytics to optimise its supply chain and create tailor-made offerings for customers, thus having a higher control over demand forecasting and product development.

Trumpf is using data-driven optimisation in their new 'pay-per-part' business model. Instead of buying an asset, the customer pays for the generated output (lasered metal parts). The main business value is the increased efficiency gained from the data-driven optimisation of the operation for which Trumpf is responsible but also rewarded.

Questions to address before moving to a Data-Driven Business Model

What do we want to achieve by using data?
Many organisations understand the potential value of data, but they don't always have a clear plan for how to use it. This can lead to wasting a considerable amount of time on useless activities, resulting in unnecessary costs and misuse of resources that could instead be dedicated to other productive activities. Organisations must take the time to define their specific goals before they start collecting and analysing data, so that they can be more efficient and effective in these tasks. They will also be more likely to achieve their desired results.

What is our desired offering?
Companies need to decide if their DDBM will either improve their current offerings or create new ones. Companies can have multiple offerings, and established ones tend to have a variety of products or services where often data is used to improve the current ones. As explained, data can be offered in a raw or elaborated format, and the output of data analytics typically includes insights or applications into customer behaviour, preferences, and needs that can be used in a variety of ways to improve customer offerings (e.g. develop new products or services), as discussed in Chapter 3 (Data-Driven Business Models section).

What data do we require and how we are going to acquire it?
Companies need to be strategic about the data they use in their DDBM. They should focus on only collecting data that are relevant to their business goals and that can be used to improve their customer offerings. Companies should also consider how they will acquire the data they need. For instance, by generating their own data internally or obtaining them from external sources. They can generate data manually, through sensors and tracking tools, or through crowdsourcing.

In what ways are we going to process and apply these data?
Data processing methods reveal the true value of data. Companies need to know which key activities they will use to process data so that they can plan accordingly and make sure they have the necessary hardware, software, and skilled employees. Data analytics is used to generate insights from data. Analytics can be subdivided into three categories: a) Descriptive analytics: explains the past, b) Predictive analytics: predicts future outcomes, and c) Prescriptive analytics: predicts future outcomes and suggests decisions.

How are we going to monetise it?
Companies need to have a clear goal and quantifiable benefits in mind before they build and implement a DDBM. For instance, this involves having a clear understanding of the goals of the DDBM and how it will be used to generate revenue. There are many different ways that businesses can generate revenue from a DDBM (e.g. new products/services). Companies can also generate revenue from their DDBM by selling data or data-powered insights to other businesses, acting not only as data users but also as data suppliers or data facilitators. It is important to note that not all DDBMs are designed to generate revenue directly. Some DDBMs are designed to improve internal processes or make better decisions thus improving financial performance by reducing costs. Overall, a revenue model is an essential part of any successful DDBM. By having a clear understanding of how they will generate revenue from their DDBM, businesses can ensure that it is a worthwhile investment.

What are the barriers to accomplishing the goal?
While many benefits can be identified, companies must also find ways to overcome the frequent barriers that might prevent an effective application of the DDBM. Among these barriers, it is possible to find cultural problems, personal issues, value perception, data availability and accessibility, data quality and integrity, data and analytical skills, departmental collaboration issues, legal challenges, data privacy obstacles, resource and hardware issues, practicality issues.

Artificial Intelligence economy: from human intelligence systems to artificial intelligence systems

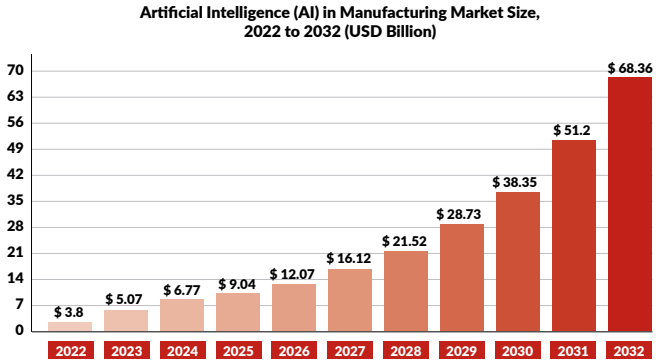
Artificial Intelligence market size and trend in manufacturing

According to market research carried out by Precedence Research and Market Research Future, the global market for Artificial Intelligence in manufacturing is expected to grow by 2025 at a CAGR of 33.5%., hit 30+ billion USD by 2030 and increase 10-fold by the year 2030 [41] as reported in Figure 8.

Figure 8

Trends in the Artificial Intelligence market worldwide

(Source: Precedence 2023)



Artificial Intelligence business models context

Human beings have always been curious about technology like intelligent robots taking over the world, where stories like the movie "Terminator" used to make us afraid; on the other hand, the possibility of new romantic relationships with ChatGPT nowadays has completely flipped the scenario. In the business industry, innovation is always a game-changer. Companies use information technology for product maintenance, service operations, repairing equipment, and collecting information about user behaviour. This information is used by the firms for decision-making. One of the primary functions of Artificial Intelligence is decision-making and productivity boost, where human errors are minimised to gain maximum profit. For instance, McKinsey Global Institute reported that by 2030, applications of AI will boost global productivity by 1.2% annually, increasing the size of the global economy by USD 13 trillion[42]. Accenture reported estimates that AI will add USD 8.3 trillion of value to the US economy by 2035[43]. However, it is difficult to integrate AI into traditional business models[44] but nevertheless, most desired. In the context of servitisation, AI is part of digitalisation and thus it will 'aid servitisation'[45]. For manufacturers, digitalisation has enabled the delivery of service-based solutions through productive capabilities. Servitisation provides a means for customisation and AI can allow mass customisations and provide competitive advantage.

Defining AI and business model innovation

There is a general consensus among publishers not to agree on a single definition of AI. However, the most useful shall be provided, nonetheless. As a subject, "Artificial intelligence (AI) is a field of computer science devoted to creating computing machines and systems that perform operations analogous to human learning and decision-making"[46], but a more futuristic definition could be "AI holds the potential to transform virtually every facet of modern manufacturing, from how products are designed, fabricated, and assembled to how factories operate and supply chains integrate to how products are sold, serviced, and consumed in the field"[47]. "AI technology can provide the foundation for successful digital servitisation and business model innovation, simply spending money on digital infrastructure, technologies, and data is not enough. New routines, skills, operational processes, and business models are required in making use of AI technology to create value for customers"[48]. AI capabilities act as an enabler in companies to move from product-centric models to advanced digitally enabled business models with higher expectations for value generation.

Key challenges and barriers to Artificial Intelligence development and adoption

One of the key challenges or criticisms AI technology has faced thus far has been that too much automation will cause the loss of human jobs. According to one study, it is expected that 46% of traditional job descriptions will become obsolete, and human resources will be transferred to more project-oriented work rather than routine tasks. However, five industries, including textile & apparel, consumer electronics, chemicals, automotive, and industrial equipment, are expected to observe a 16% displacement in jobs[49]. AI-based automation will generate new jobs to support robots and their maintenance. However, the adjustment will be costly as workers will be searching for new jobs and will need to retrain.

AI capabilities are perceived as expensive, for instance with Natural Language Processing more than half of IT professionals (54%) reported it as a cost challenge. This is more prominent in Western Europe—60% in France, 58% in Spain—and South Korea (66%) than in China (45%) or the US (43%)[50].

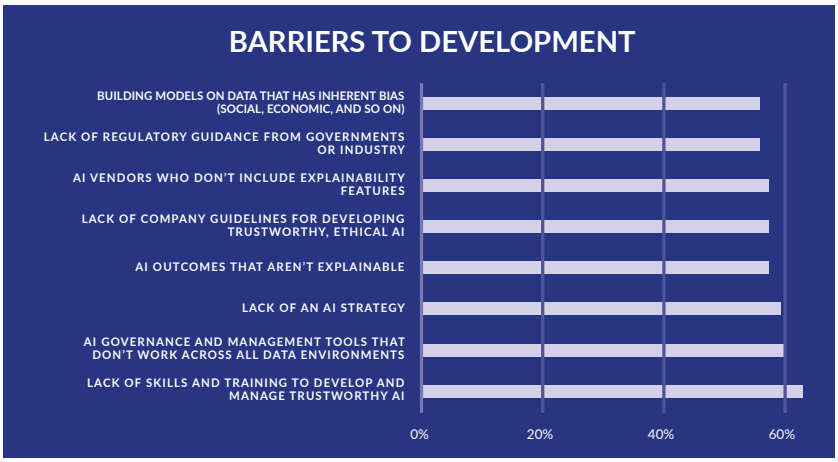
According to the IBM Global AI Adoption Index 2022,

more companies (35%) adopted AI, a 4% increase from the previous year, 2021. Despite 42% showing interest, only 54% of AI projects made it from testing to actual use. The journey from trying out AI to making it work seems to be a bit bumpy for many businesses. These journeys could be made easier with the identification of development barriers and resolving them. It is observed that the barriers are down 2%-3% compared to 2021. (see Figure 9) .

Figure 9

Barriers to development

(Source: IBM Global AI Adoption Index 2022 | May 2022)



Examples of Artificial Intelligence business models

Since the 1970s AI has been employed for the optimisation of manufacturing systems to support decision-making. Machine layout and task scheduling were initially heavily impacted by modelling flexible systems. However, there were no booms like we see today; this change happened after 1990, when the introduction of Artificial Neural Networks (ANN) caused the emergence of intelligent agents and deep learning of large datasets [51]. After machine learning, the data was recognised as the basis for lean, agile, and energy-efficient systems. Words like Industry 4.0 and smart manufacturing are used to emphasise automation at all supply chain levels while making production more fulfilling in terms of time and custom size constraints. More examples related to automation comprise the inclusion of new business processes in manufacturing. Predictive maintenance[52 53 54], energy management optimisation[55 56], involving customers in the design phase[57 58 59], and plant-wide control[60] are some of the AI-enhanced capabilities.

Furthermore, autonomous vehicles (AVs), robotics, and human and robot collaboration caused massive dynamic exploitation of resources that concluded in systems being smart in terms of planning as well as scheduling[61] (see Figure 10).

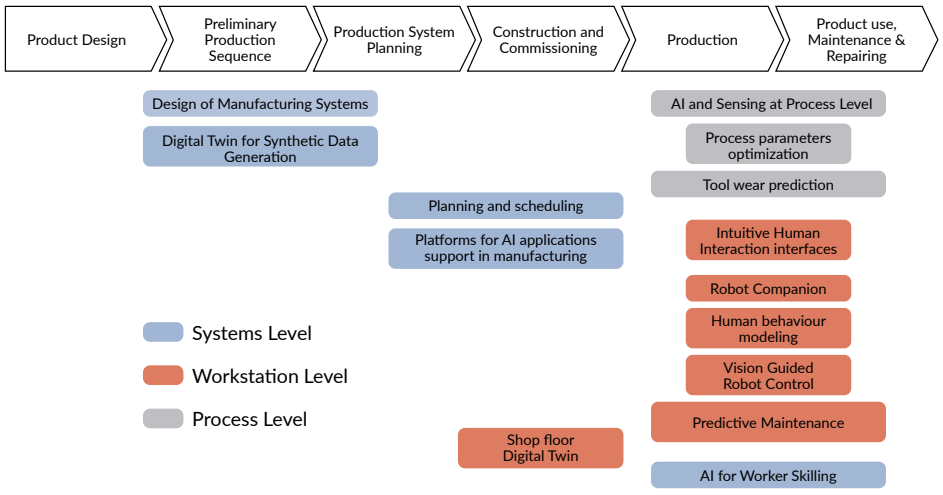


Figure 10

Use cases and examples AI business models based on AIM-NET

(the Artificial Intelligence in Manufacturing Network – AIM-NET. 2023. "ARTIFICIAL INTELLIGENCE IN MANUFACTURING White Paper." 2023. https://www.aim-net.eu/.)

Mass Customisation economy: from mass-products and services to mass-customised and personalised products and services

Context and challenges: Future customers demand customisation and personalisation

Markets, demand, and business models have changed drastically over the past decades in response to global societal developments and technological advances. For example, despite the success of Ford in its early days, particularly due to improvements in productivity and cost reductions, this business model based on standardisation is no longer capable of ensuring the competitiveness of the company. Now is the time to create customised, personalised, and even individualised products and services to meet the needs of current and future customers. According to a survey conducted in 2022 among 3,450 consumers, more than half of these are not satisfied with the personalisation experience offered by several brands[62]. In another recent study, 87% of companies assume that they provide a good customer experience, while only 11% of customers agree[63].

These demands for high variety, customised and even personalised products and services are not new and can be seen everywhere. Well-known for many years is the success of the automotive industry in developing specific configurations of cars to suit individual customer demands. One of the well-known examples of car customisation was when Fiat developed the retro Fiat 500 and created the online platform called "Concept Lab", where customers could express their preferences regarding the interior of the car. This resulted in more than 160,000 design concepts based on particular customer needs, before the car was even launched[64]. Today, almost all automotive companies offer advanced online car configurators, where customers can play with a variety of options to find the configuration that matches their exact needs. Further, the apparel and fashion industry was another early adopter of the customisation potentials, where the "Levi's Personal Pair" initiative started as early as in the '90s. Today, customised clothing, shoes, handbags, etc. can be found everywhere and are embraced by many big sports and fashion brands as additional premium options offered alongside standard products, as well as by entrepreneurs and niche market players focusing solely on the opportunity to make tailor-like products at a low cost. Back in 2015, the Deloitte Consumer Review showed that 19% of consumers have purchased customised products or services in the clothing retail category, while 64% are aware of the customisation options in this category[65].

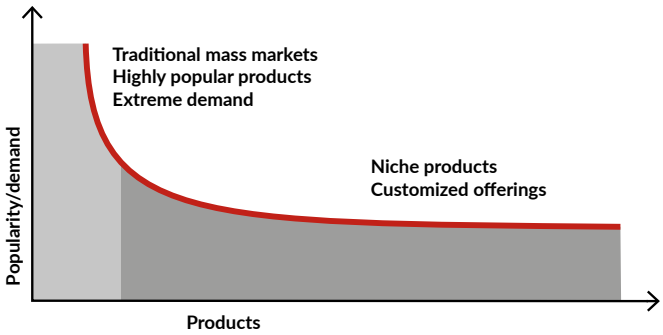
In addition, trends of increased variety and customisation are obvious in many additional product and service markets, e.g. in electronic goods, TV and streaming services, educational services, food and groceries, restaurants, hotels, medical products, beauty and health, furniture and homeware, etc. where unique customer experiences are created from customised offerings. Furthermore, in the business-to-business segments, customisation can also be recognised as an increasingly important competitive characteristic, e.g. due to private labelling or a high need for specifically engineered-to-order products or services.

The driving forces of increased variety, customisation and personalisation are both market and society related, but also driven internally by companies worldwide. First and foremost, markets have expanded globally for the past decades, which means an increasing number of market segments, new local/regional requirements, demand for product features, changing regulations and not least, increased competition and pressure for differentiation. Thus, companies worldwide have responded by seeking new ways of creating higher customer value, competitive edge, and reaching new markets. Sometimes, this type of selling strategy is referred to as the "long tail", meaning that companies compete in the market by selling many different variants of niche products in relatively low quantities compared to selling a large volume of a few highly popular products[66]. Thus, 'selling less of more' is a popular expression, which explains this new competitive situation of companies in strong contrast to the mass-production paradigm. As a matter of fact, according to a recent study conducted by Twilio in 2022, more than 90% of the surveyed companies consider that customisation increases customer loyalty. A similar observation was drawn from a study by Coresight Research[67], with 71% of the customers being likely to shop more often from brands offering customisation (see Figure 11).

Figure 11

Illustration of the long tail market

(Source: Anderson, C., Nissley, C., & Anderson, C. (2006). The long tail. DeGruyter)



The underlying assumption or condition in the 'Long Tail' is that markets contain a few extremely popular products that are extremely high in demand, while at the same time containing many niche products that are less high in demand but satisfy a variety of customer needs. In other words,

markets and customer demand is becoming increasingly diversified and heterogeneous. Thus, only a few companies will be able to become market leaders offering one or a few extremely popular products or services. Rather, most companies will be faced with the challenge of diversifying their offerings of goods and services to be able to respond to a wide range of customers. In this regard, it makes sense to differentiate between the following ways of satisfying heterogenous customer needs:

- **Variety:** the assortment of products and services offered and sold to the customers.
- **Customisation:** providing high variety and customisation of products and services so that (almost) everyone can find what they need.
- **Personalisation/individualisation:** offering the exact product or service that matches the individual customer need, i.e. markets of one!

The bottom line is that variety and customisation are no longer simply something that a few customers appreciate, but basically a demand that should be considered and satisfied in an economically feasible way in all markets and industries now and in the future. In the McKinsey Next in Personalisation 2021 Benchmarking Survey, it was emphasised that following the COVID-19 pandemic, personalisation matters more than ever, as consumers have increasingly become accustomed to online interactions, and many have changed their buying behaviour[68]. It was estimated from the survey that 75% of consumers tried a new shopping behaviour during the pandemic and that 71% of consumers expect personalisation from the brands and businesses they engaged with. Furthermore, it was estimated that more than three-quarters of consumers valued personalisation of communication as a key factor influencing the likelihood of purchasing, recommending, and repurchasing from brands and businesses[69]. Likewise, in the 2015 Deloitte Consumer Review, an average of 36% of consumers expressed interest in purchasing personalised products or services and 48% indicated that they were willing to wait longer for a personalised product or service[70]. Thus, customers no longer just demand customisation and personalisation in physical product offerings, but also in the services, marketing, and interactions with companies and brands they engage with - they want personal experiences.

The benefits of product and service diversification are numerous, e.g. the possibility of a competitive edge, value competition over price competition, entering upper market segments, price premiums, unique customer relations, etc. Deloitte's research shows that already in 2015, 1 out of 5 consumers who expressed an interest in personalised products or services was willing to pay a 20% price premium[71].

However, this diversification also leads to increased internal complexity and the challenge of making profits from heterogeneous customer demand in contrast to making profits from serving a large pool of homogeneous customers through standard products/services. This challenge obviously links to the increased number of different resources to be implemented to ensure satisfactory diversity of the offer and the high volumes of information and data to process. Added to this problem is the need to shorten the development and marketing time of personalised products and/or services to cope with market volatility and competition that goes beyond the classic price war. The challenge is to ensure competitiveness on the cost-delay-quality triptych, but also in terms of agility and resilience, as well as a stronger link to the customer.

Thus, some costs associated with increased variety, customisation, and personalisation may include higher holding and inventory costs, increased changeover and setup time costs, increased design and development costs, increased costs for quality assurance, etc. Reaching "mass-production"-like costs without having standard product and service offerings with mass sales is a main challenge for companies that want to develop increased customer-orientation and customer-centricity by customising and personalising products and services.

Customer-orientation is often defined as focusing all enterprise and supply chain operations on servicing customers' unique value and by treating customers as individuals[72]. This was mainly developed in the field of marketing and was then gradually integrated into project and operations management. Unlike the era when mass production reigned, customer expectations and satisfaction are now among the primary concerns of manufacturing and service companies[73]. Consequently, customer-centred strategies such as mass customisation have gained popularity.

Mass customisation: definitions, enablers and typologies

Mass customisation is not a new term - it has been recognised and widely popularised as a competitive business model pattern since the early '90s. As Pine have pointed out[74]; the core aim of mass customisation is to cater to the unique requirements of individual customers while maintaining production efficiency that comes close to mass production. Various definitions of mass customisation have been recognised, e.g.:

- *"Developing, producing, marketing and delivering affordable goods and services with enough variety and customisation that nearly everyone finds exactly what they want"*[75] (Mass Customization – The New Frontier in Business Competition)
- *"Mass customization aims to deliver products and services that best meet individual customers' needs with near mass production efficiency"*[76]
- *"Mass customization is defined as the making of tailor-made goods or services in an economically viable manner"*[77]

In contrast to pure personalisation or craftsmanship, mass customisation seeks to meet customer needs at a reasonable cost. In essence, it strikes a balance between the economies of scale associated with mass production and the personal touch of tailor-made products. Thus, "mass" is important, however, not in the traditional sense, as mass customisation aims at reaching "mass-production"-like costs without having standard product and service offerings with mass sales, i.e. efficiently serving customers in a unique way.

In this way, mass customisation can be seen as an evolution of both mass production, but also traditional craftsmanship. While the past manufacturing paradigms have relied both on a pull-like craft production concept and a push-like mass production concept, mass customisation and personalised production appears to be the way forward for meeting the demands of future customers, markets and societies (see Figure 12).

Figure 12

Product volume vs product variety

(Source: Koren, Yoram. The global manufacturing revolution: product-process-business integration and reconfigurable systems. Vol. 80. John Wiley & Sons, 2010)

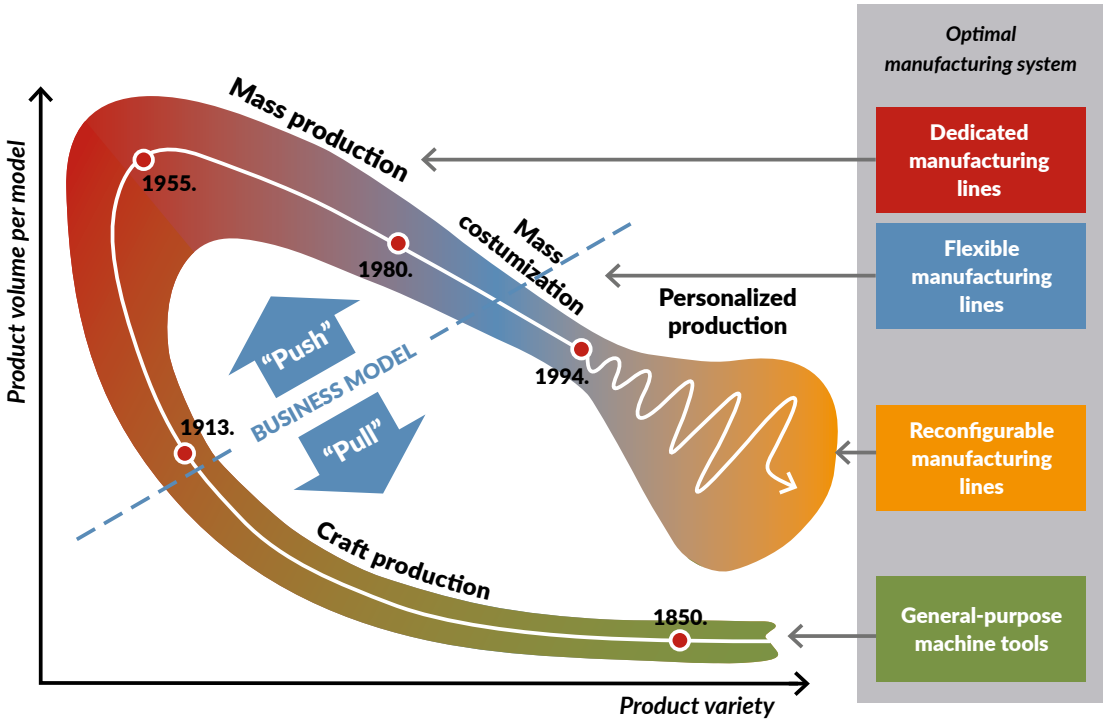
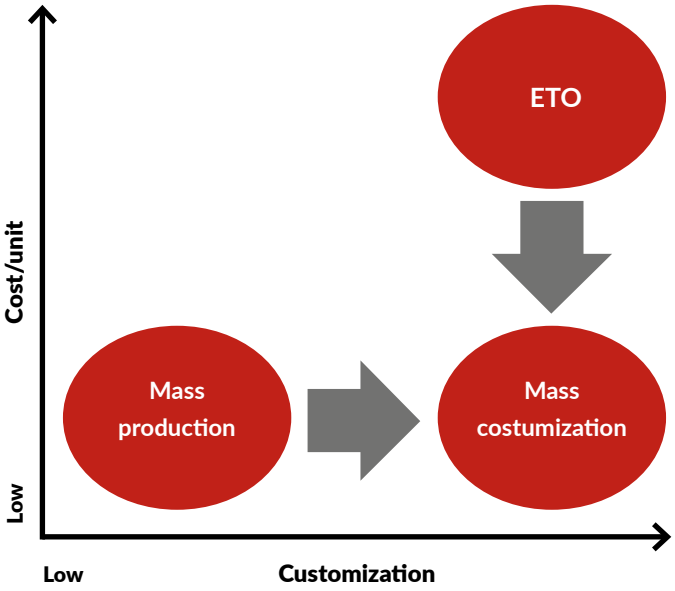


Figure 13

Pathways to mass customization



Following this distinction, mass customisation can be considered as an extension of mass production, i.e. going from standardised products/services to customised products/services, but maintaining cost efficiency. Mass customisation can also be an approach of increasing cost efficiency in engineer-to-order businesses, i.e. standardising and modularising products/services (see Figure 13).

The potential benefits of mass customisation are numerous. From the viewpoint of the customer or consumer, benefits include increased satisfaction by getting the exact product or service needed and increased value for money. From the business or producer's perspective, mass customisation can provide a unique competitive advantage, increased customer loyalty, higher profit margin, price premiums, reduced cost of variety (greater economies of scale), increased global competitiveness, the possibility of entering "upper" market segments, competing on value rather than price, and a closer relationship to customers. In the McKinsey Next in Personalization 2021 Benchmarking Survey, it was also indicated that companies with faster growth rates derive 40 percent more of their revenue

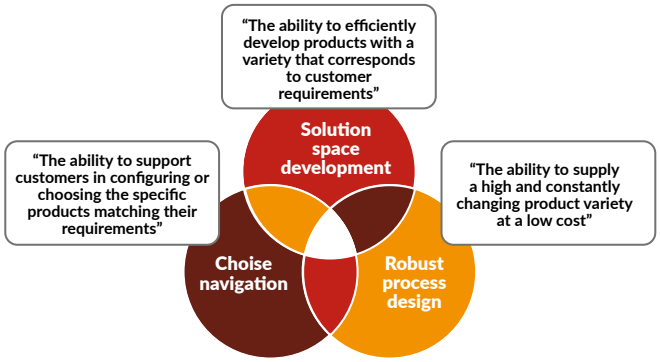
from personalisation than slower-growing counterparts of companies[78]. Additionally, many current trends in today's societies drive mass customisation, e.g. increased online shopping resulting in the broadening of markets and larger customer bases, an increased use of social media and the wishes of consumers to display uniqueness, the need for local adaptations in global marketplaces, etc.

The success of mass customisation is contingent on various factors, particularly 1) external factors like diverse customer demands, i.e. there needs to be a requirement for diversification in the market, and 2) internal factors such having the right set of capabilities[79]. In the highly popular research paper from 2009, "Cracking the code of mass customization" by Salvador, Holan and Piller, the three fundamental capabilities of mass customisation were described; solution space development, choice navigation, and robust process design (see Figure 14).

Figure 14

Three fundamental capabilities of mass customization

(Source: Salvador, Fabrizio, Pablo Martin De Holan, and Frank Piller. "Cracking the code of mass customization." MIT Sloan management review 2009)



Solution space development is ultimately about identifying the different needs of customers in terms of the product or service attributes where customer needs diverge. The key point is that customers are different, and their needs are different, thus, the range of options and features (solutions) that customers need is heterogenous and unique to every customer. Therefore, the solution space should be carefully designed based on market research and understanding customer needs to succeed with mass customisation. There are many types of customisation that can be developed to suit customer requirements. For instance, customisation can appear in terms of functionality, form, fit, comfort, etc. for a physical product in the fashion and apparel segment. Another perspective on the customisation options is that they can be offered on different levels[80]: 1) Structural level: offering of components/building blocks/modules. 2) Performance level: performance of the product when installed for the user. 3) Experiential level: special attributes of the product that relate to customer emotions and dreams. Giving the customer an experience. 4) Learning level: resulting in further impact for the customer and end-user. These customisation levels are close to the ideas of the experience economy, where customisation increases the value provided and is able to create unique experiences relevant to the individual customer[81].

While solution space development is essentially about deciding how to offer customisation and personalisation options to customers, choice navigation is essential in supporting customers in navigating these choices. Choice navigation is about creating models and support for customers, creating the ability for customers to construct their preferences and/or evaluate the alternative designs offered to satisfy their own needs, enabling a collaborative customisation strategy, and enabling the customer to create their own designs. The successful implementation of choice navigation can lead to customer loyalty, an excellent customer experience, the simplification of customer decisions, and limiting the complexity and burden of choice. Obviously, developing successful choice navigation can leverage new information technologies and online platforms, i.e. configurators that can be used by customers.

Finally, to efficiently deliver the customised products or services to the customer, robust process design is needed in all operations and supply chain processes. Some well-known ways of designing robust processes are by using: 1) flexible automation/reconfigurable manufacturing systems that provide exactly the adaptability and changeability needed for customised offerings, 2) product and process modularity, adaptive human capital, and delayed differentiation.

Over the past two decades, substantial research efforts have been devoted to developing methods and tools that facilitate the efficient design of products, production systems, and supply chains within the framework of mass customisation[82 83]. Concurrently, another stream of literature has underscored the importance of coordination among various actors within the supply chain, leveraging Information Technology (IT) to deliver mass-customised products[84 85]. For a comprehensive overview of the concept and tools related to mass customisation, you can refer to the thorough literature review conducted by (Fogliatto, F. S., Da Silveira, G. J. C. et Borenstein, D. (2012)[86].

To comprehend the concept of mass customisation, several classification systems have been developed to delineate distinct levels of customisation and the factors that facilitate them. Many of these classification systems are rooted in the concept of the Customer Order Decoupling Point (CODP)[87]. The CODP serves as a pivotal point in the supply chain, demarcating the segment that directly responds to customer demands from the portion that relies on forecast-based planning.

Customisation spans a spectrum, ranging from the highest levels where customers actively participate

in the early design phases, to the lowest levels where customer preferences are considered only during product delivery. For example, if the CODP is closely tied to the final customer, it signifies mass production rather than customisation, while limited customisation can be achieved when the CODP is situated within the retailer's facilities. Greater degrees of customisation can be attained when the CODP is positioned within the manufacturer's premises[88 89].

Mass customisation and personalisation as a way of creating the greatest unique customer value

While the concept of mass customisation is not new and has roots in the early '90s, it can indeed by recognised as a strategy for most businesses now and in the future. Mass customisation has proved to be the key to growth and success in many companies historically, but is also difficult to implement in many cases[90]. Some main challenges from a manufacturing point of view include data management and collection challenges that support defining customer wishes and needs, balancing customisation and the cost/complexity of internal operations, i.e. maintaining mass cost while providing more variety, and new organisational changes needed to make mass customisation a scalable business[91].

In the "Mass Customisation 500" (www.MC-500.com) study, 500 companies offering customised consumer goods were investigated. It was concluded that the key to profiting from mass customisation is to treat it not as a 'standalone business strategy' that replaces the entire existing business, but rather as a set of capabilities and strategic mechanisms that can enrich and supplement the existing business model of a company in most industries and segments. In other words, mass customisation is a strategic mechanism to align the organisation, products, and services with the customer needs by deploying the three foundational capabilities, as there is no 'one-size-fits-all' approach.

Thus, a variety of successful mass customisation business models can be developed that exploit and transform heterogeneous customer needs into profit relying on the capabilities of mass customisation.

Servitisation economy: from products to services and product-service systems

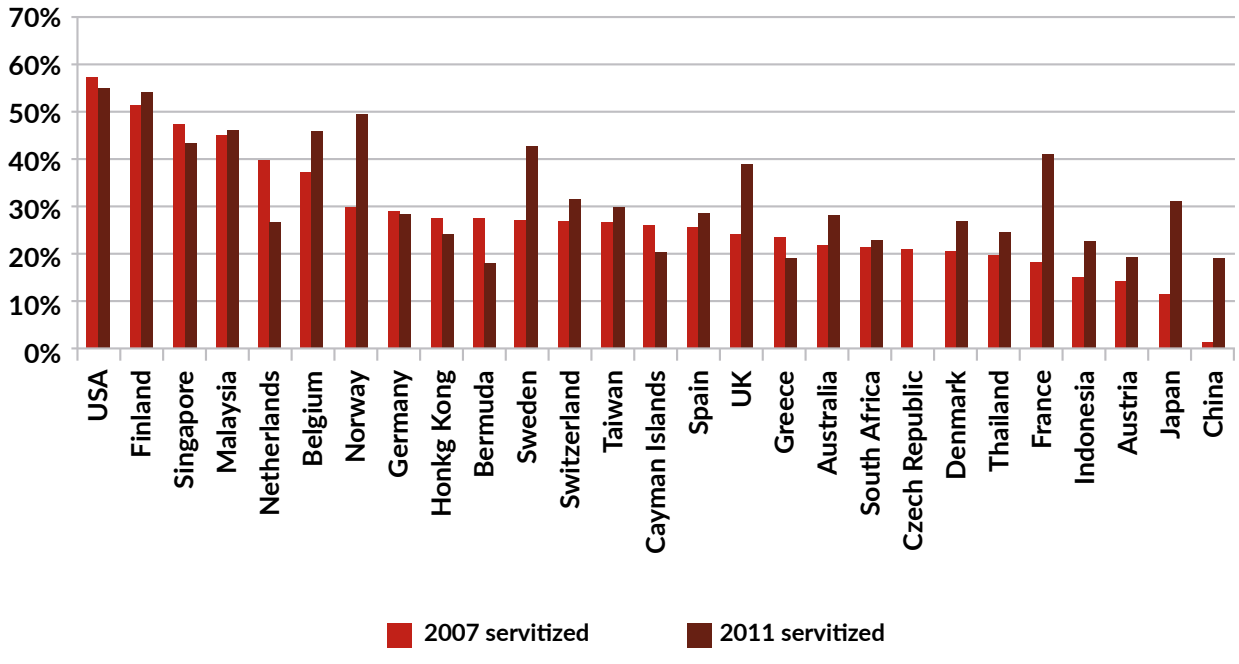
Global trends in servitisation

Different studies have been conducted since the late '80s to understand the extent and relevance of the servitisation process among manufacturing companies. To date, as reported in Figure 15, a study conducted in 2011 reveals an increasing trend of the servitisation extent in 27 countries from 2007 to 2011[92].

Figure 15

Servitization trend

(Source: Neely A, Benedettini O, Visnjic I (2011) The servitization of manufacturing: further evidence. 18th Eur Oper Manag Assoc Conf 1)



Focusing on the European manufacturing context, a study conducted in 2014 shows that around 86% of the 3,693 companies examined offer at least one service[93]. In some countries, the servitisation trend in manufacturing experienced a radical increase up to 2019, such as in China (up from 1% in 2007 to 38% in 2019). In 2019, North America and Oceania were the most servitised geographical areas, and the UK and USA were among the most servitised countries[94] (see Figure 16).

Figure 16

Servitization diffusion

(Source: Mastrogiacomo, L., Barravecchia, F., Franceschini, F. (2019). A worldwide survey on manufacturing servitization. Int J Adv Manuf Technol 103, 3927–3942)

These outcomes support the relevance of the servitisation process in manufacturing companies, even though it does not show the same extent in all countries. These differences can be explained in many ways, among which the local markets, the management culture, the aversion to risk, the customer proximity, the availability of specialised skills, and the spread of important enabling technologies.
What is the current situation? A recent survey involving more than 300 manufacturing companies worldwide showed that nowadays, servitisation is embraced by companies that are expanding their business portfolios with service offerings[95]. They mainly offer services that are strictly related to the product, such as spare parts delivery, repairs, warranties, maintenance, retrofitting, and upgrading. Training, consulting, and engineering are also widely offered. Integrated solutions of products and services are also present in the business portfolio of these companies, specifically: long-term maintenance contracts, pay-per-use, full-service contracts, and outcome-based contracts. However, a difference between large enterprises and SMEs was observed in the delivery of these more advanced solutions, which may be linked to the difficulty in structuring these types of services (see Figure 17).

The study also reveals that nowadays, the main source of revenue in the manufacturing world is still the sale of new products. However, the increasing trend towards the provision of services is well documented.

Servitisation of manufacturing: definition and examples

Servitisation is the transformation process of companies moving beyond the mere provision of products to selling integrated solutions of product and services (i.e. Product-Service Systems) that enhance the value delivered to customers[96 97]. This strategic shift is often pursued to foster closer customer relationships, generate stable revenue streams, and differentiate a company from its competitors[98]. Servitisation can also provide environmental benefits through dematerialisation by promoting the efficient use of resources and cleaner technologies[99].
Think of a manufacturing company that produces and sells its machine tools. If, traditionally, its business is focused on just producing and selling the machines, after having embraced a servitisation process it ends up by producing and selling the machine tools in addition to a contracted support and maintenance service on these machines.

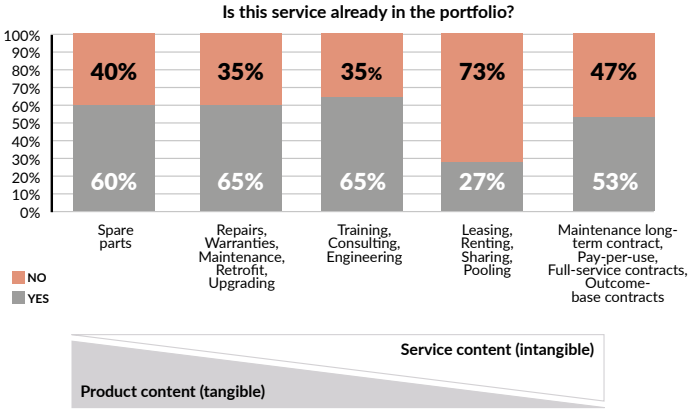


Figure 17

Service typologies

[Source: Pezzotta, G. et al. (2023). The Digital Servitization of Manufacturing Sector: Evidence from a Worldwide Digital Servitization Survey. In: Alfnes, E., Romsdal, A., Strandhagen, J.O., von Cieminski, G., Romero, D. (eds) Advances in Production Management Systems. Production Management Systems for Responsible Manufacturing, Service, and Logistics Futures. APMS 2023. IFIP Advances in Information and Communication Technology, vol 690. Springer, Cham]

The phenomenon of servitisation was identified in the late '80s. Over the years, many manufacturing firms have spotted the opportunity of exploiting a servitisation strategy in manufacturing to provide integrated solutions of products and services rather than making standalone products or selling services. Some examples are:

- Rolls-Royce competes by providing airlines with "Power By The Hour" — selling the jet engines along with the services to maintain, repair and upgrade them over many years.
- Philips provides "Light as a Service" to its customers who rent lamp and lighting systems from Philips, and in turn, Philips is responsible for all of the post-sale service, repairs, and replacements during the period of the service contract.
- ABB offers a range of services, including maintenance, repair, and remote monitoring, that help to improve the performance and reliability of its products. Additionally, ABB offers digital services that use data analytics and artificial intelligence to optimise the operation of its equipment and reduce downtime.
- Xerox started by selling photocopiers and photocopy paper and turned into full-service printing, photocopying and scanning solutions; they have also branched out into the wider field of 'document production and management', along with training solutions.
- Alstom offers the TrainLife Services (TLS) package - including services such as condition-based maintenance, support for managerial and technical operations, and performance improvement – supporting customers' need for a reliable, quality service.

Servitisation of manufacturing types

What are the main types of servitisation?

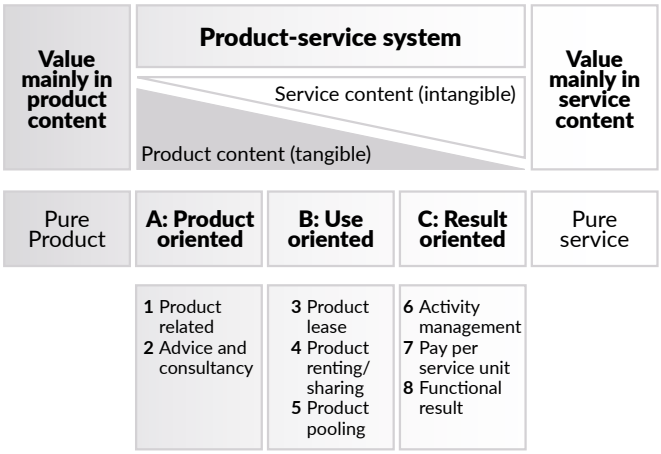
While servitisation can manifest in numerous ways depending on the industry and company, there are three main types commonly observed[100] (see Figure 18):

- **Product-oriented Services:** These are basic after-sales services related to the product that the customer needs during the use phase of the product or at its end of life, such as repair, maintenance, and spare parts provisioning, take-back agreements. They often function as value additions to the core product offering.
- **Use-oriented Services:** Here, the focus shifts from ownership to usage. The traditional product still plays a central role, but the business model is not geared towards selling products. Indeed, customers pay based on their usage, as seen in leasing or renting arrangements. The product remains under the ownership of the manufacturer but is made available to the customer as and when required.
- **Result-oriented Services:** In this model, customers pay for the results or outcomes, not the product itself. For instance, a manufacturer might guarantee a certain uptime for machinery, and any downtime beyond that might entail penalties or compensations. Here, the ownership rights are retained by the manufacturer, therefore the customer loses control of the product but gains in risk sharing since risks are assumed by the manufacturer itself.

Figure 18

Product-service system

(Source: Tukker, A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Business strategy and the environment, 13(4), 246-260)



There would be variations in the product and service proportions, as well as business activities, across these three categories of services. However, the key concepts that transform in the value transition from pure product to pure service are tangibility, transfer of ownership, time of generation and consumption, participation of the user, and quality of relationship between producer and user.

To support industrial enterprises in their servitisation process, the main drivers, enablers and challenges of this transformation process are detailed in the following sections.

Servitisation of manufacturing drivers

The drivers of servitisation are multifaceted, stemming from both the external business environment and internal strategic considerations[101 102 103]. Together, they shape the ongoing shift from traditional product-centric models to integrated product-service systems.

One of the primary external drivers is the intensifying **global competition**, with firms constantly seeking avenues to differentiate their offerings in saturated markets. By integrating services with their core products, companies can create unique value propositions, setting themselves apart from competitors. This strategy often results in deeper customer engagement and loyalty, since the provision of services typically fosters a more

intricate, ongoing relationship between providers and clients. Another influential external force is the **evolving customer expectation**. Today's consumers, both in the B2B and B2C sectors, increasingly demand solutions rather than standalone products. They seek holistic experiences and outcomes. For instance, instead of merely purchasing a piece of machinery, a company might desire a comprehensive package that includes installation, maintenance, and performance optimisation. This shift in customer demand is pushing companies to bundle products and services as comprehensive solutions.

Technological advancements have also played a pivotal role in driving servitisation. The proliferation of the Internet of Things (IoT), advanced data analytics, and Artificial Intelligence (AI) has enabled firms to monitor products in real time, predict maintenance needs, and tailor services to individual customer requirements. These technologies not only facilitate the delivery of services but also offer data-driven insights that can lead to continuous product and service improvement.

Internally, companies are motivated by the allure of **stable revenue streams**. Traditional product sales, especially in industries like manufacturing, can be sporadic and cyclical. In contrast, service contracts, especially those that are subscription-based, offer a more predictable and recurrent revenue source, which can be especially valuable during economic downturns. Moreover, there is an increasing recognition of the potential for enhanced profitability through services. While initial investments in servitisation can be substantial, the long-term revenue from service contracts, combined with the potential for cross-selling and upselling opportunities often results in improved profit margins.

Lastly but not in terms of importance, **sustainability** is a driver for embracing the servisation process. Through services and a combination of products and services, it is possible to extend the lifespan of the products which strongly incentivises the equipment owner to minimise operating costs, in particular energy use, which is the largest cost component over the lifecycle of the equipment. Servitisation changes consumption patterns from linear to more circular patterns, since keeping ownership of the equipment also encourages the development of modular systems, which is key to a circular economy. Thus, servitisation pursues resource efficiency and dematerialisation.

Servitisation of manufacturing enablers

The journey towards servitisation for many companies is not solely driven by the recognition of its potential benefits but is enabled by a variety of technological, organisational, and strategic factors that make this transformation feasible and effective[104 105].

From a **technological** standpoint, the rise of digital innovations has been a cornerstone in the servitisation trajectory, leading to the transformation process known as Digital Servitisation. The IoT, in particular, allows firms to connect physical products to digital networks, facilitating real-time monitoring, predictive maintenance, and responsive service delivery. Connected devices can relay information about their status, usage, or environment, enabling companies to offer timely and relevant services. Further enhancing this capability is advanced data analytics. With the vast amount of data generated from connected products, analytics helps companies derive actionable insights, tailor their service offerings, and anticipate customer needs. Additionally, AI and machine learning algorithms empower companies to automate and optimise various service processes, ensuring efficiency and precision.

Organisational capabilities also play a pivotal role. A company's ability to restructure and retrain is fundamental. Transitioning to servitisation often requires firms to develop new skills and competencies, especially in customer relationship management, service delivery, and solution development. This might involve comprehensive training programmes, the hiring of new talent with specialised expertise, or even forging partnerships with service-focused entities. Internally, fostering a culture that values service excellence is equally paramount. Employees across the organisation, from leadership to frontline staff, need to align with the vision of delivering holistic solutions rather than mere products.

Strategically, the shift to servitisation is underpinned by market insights and customer intimacy. Understanding customer needs, preferences, and pain points is central to crafting compelling service offerings. This necessitates effective feedback mechanisms, close collaborations, and sometimes even the co-creation of solutions with customers. Moreover, the development of flexible business models that cater to diverse customer requirements is essential. For instance, while some customers might prefer performance-based contracts, others might opt for subscription models or pay-per-use arrangements.

In the backdrop of these enablers, it is also worth noting the role of regulatory and policy frameworks. In certain sectors, regulations might promote or necessitate the adoption of service-based models, especially when sustainability, circular economy principles, or product stewardship are legislative priorities.

Servitisation of manufacturing challenges

Servitisation, while presenting a multitude of opportunities for companies to diversify their revenue streams and strengthen customer relationships, does not come without its set of challenges[106 107]. These obstacles span across various domains, from organisational dynamics to customer relations.

From an organisational perspective, one of the foremost challenges is the **cultural and structural transformation**

required. Traditional product-centric firms often have ingrained cultures that prioritise tangible goods over services. Altering this mindset to appreciate the value of intangibles, such as customer relationships, service excellence, and solution provision, can be demanding. Moreover, the requisite skills for a service-oriented approach might differ from those in a product-centric model. The need for **new competencies**, from service design to customer relationship management, may necessitate extensive retraining or new hiring, which brings its own set of complexities.

Operational challenges are also prevalent. Integrating service operations with existing product processes, especially in firms with long-established product-centric models, can be intricate. There is a need to establish efficient **systems for service delivery, monitoring, and feedback**, all while ensuring that these systems seamlessly integrate with traditional product development and sales operations. This integration often necessitates **significant investments** in technology and infrastructure at the beginning that may not always be covered by the services sales. Because of increasing costs and a lack of corresponding returns, the growth in service revenue may fail to meet its intended objectives[108]. For this reason, attention to the revenue stream is required from the development phase.

On the customer front, while servitisation aims to deepen relationships, it also introduces complexities. Crafting service agreements that align with customer expectations, ensuring consistent service quality, and managing heightened customer interactions can be taxing. Furthermore, there is the challenge of conveying the value proposition of integrated product-service offerings, especially to customers accustomed to traditional purchasing models. In this direction, a proper communication to the customers of the added value of services is required.

Circular Economy: from linear manufacturing processes and value chains to closed-loop manufacturing processes and value chains

Circular Economy context and trends

Since the Second World War, western economies have predominantly evolved within the framework of linear material and resource flows, often referred to as the 'take-make-dispose' model. In this **linear economy** model, natural resources and raw materials are taken from the environment, products are made from these materials and, when they reach their end of life, they are disposed of as waste. While this model thrived in the past, bringing economic wellbeing and contributing to the development of western societies, it has also posed several **environmental concerns**. First, the linear economic model of production and consumption relies on large quantities of easily accessible and largely available raw materials. However, natural resources such as minerals, metals and fossil fuels are finite since they exist in limited quantities on planet Earth. With an increasing pressure on these resources as the population grows in size, there are concerns about resource depletion. By comparing current production rates with the current known reserves, it is easy to determine that most metals (such as lead, antimony, indium, zinc, and silver) will cease to be available by 2030[109] (see Figure 19).

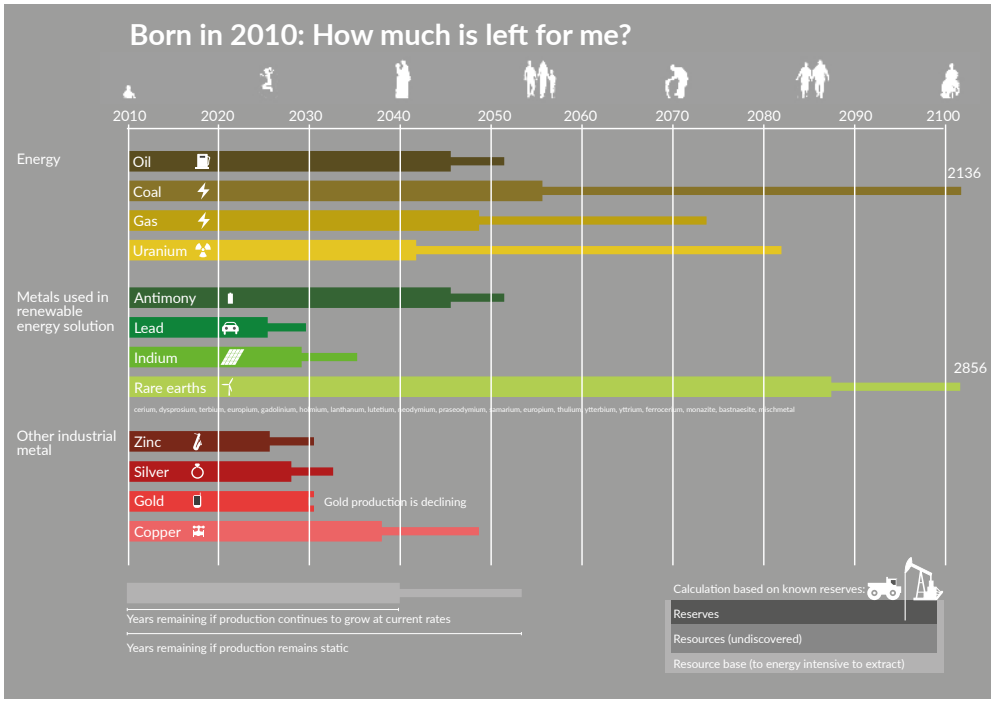


Figure 19

(Estimated) availability of natural resources

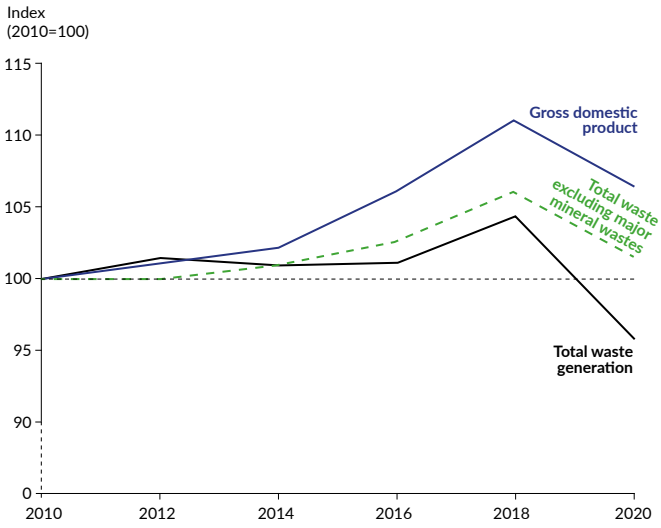
(Source: https://www.visualcapitalist.com/wp-content/uploads/2014/09/born-in-2010-how-much-metals-and-energy-is-left.png)

Second, the linear economic model of production and consumption leads to a tremendous generation of waste. Although waste generation has reduced by 4.2 % in the EU during the last decade (mainly) due to slower economic progress during the recent pandemic (Figure 20), the numbers are estimated to rise given the fast pace of economic growth. Only 30% of the waste generated in the EU per year is currently collected and recycled, with the remaining 70% ending up in landfills and oceans[110].

Figure 20

Waste generation and decoupling efforts in the EU between 2010-2021

(Source: https://www.eea.europa.eu/ims/waste-generation-and-decoupling-in-europe) energy-is-left.png)

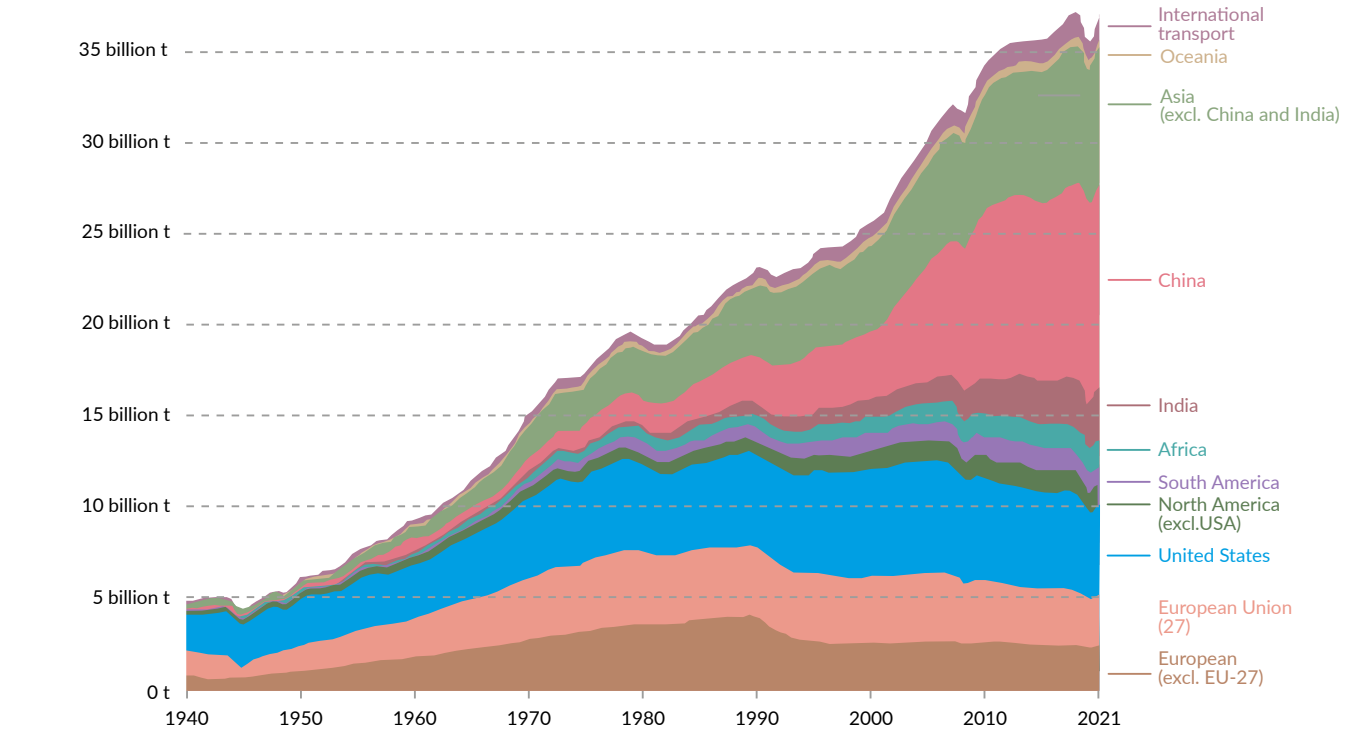


Third, linear production and consumption are highly demanding in terms of energy, which is largely produced from fossil fuel combustion. This leads to an increase in the emissions of CO2 and other greenhouse gases in the atmosphere that contribute to climate change. From the 1940s to 2021, the global annual CO2 emissions exponentially increased by a factor of 7, reaching 35 billion tons of CO2 per year[111] (Figure 21).

Figure 21

Annual global CO_2 emissions between 1940-2021

[Source: https://ourworldindata.org/greenhouse-gas-emissions#annual-greenhouse-gas-emissions-how-much-do-we-emit-each-year]



With the global population expected to grow to 9 billion by 2050[112], the linear economy model of production and consumption will no longer be sustainable. Hence, a transition towards a **Circular Economy**, which can decouple economic growth from resource extraction, is urgently needed.

Circular Economy definition

Among the several opportunities to drive our society towards more responsible production and consumption attitudes, the circular economy has gained momentum, especially in the manufacturing sector. The Ellen McArthur Foundation[113] has defined Circular Economy (CE) as *"an industrial economy to be regenerative and restorative by intention and design"* that can be established through the implementation of **circular business models**. In circular business models, resources are expected to be used in a lower quantity (narrowing), to be used for longer periods (extending), and to be reused at the end of their lifecycle (circulating)[114]. When dealing with manufacturing companies, Circular Economy can be applied through several strategies at **different micro, meso and macro systems levels**[115 116].

The ***micro level*** comprises actions undertaken by single companies that include the renovation of their internal processes, products, and business models. Under this scenario, companies are asked to implement processes like remanufacturing to reobtain the products' initial quality, or recycling to recover the value captured by the materials in use, or direct reuse of used products, after having checked their quality, to sell them into secondary markets. Through these processes, circular business models can be established, and this is facilitated especially when products are redesigned by including circular principles. Design for X approaches may smooth this process by ensuring that products would be designed to be easily disassembled, to be easily treated at their end-of-life cycles (being composed of recyclable products), and to be easily and responsibly used by consumers. These new practices and strategies at the micro level may impact on external stakeholders, like customers, who need to be engaged in this renovative path to properly align their behaviours to the updated business models. The latter can be even easier to accomplish when products are designed to be smart and thus, service-based business models can be easily established. In this particular case, tailored services could be delivered based on the consumers' behaviours facilitating a circular-oriented usage.

At the meso level, a network of companies is required to cooperate to ensure the exchange and the recirculation of resources. In this scenario, networks of companies are usually engaged in industrial symbiosis networks collaborating for the exchange of resources, that while considered waste by a certain company become useful inputs for others in their production activities. On the same wave, closed-loop supply chains can be observed at this level, among which companies belonging to the same supply chain establish both forward and reverse logistics networks to ensure the recirculation of resources at the end of their lifecycle. Lastly, all these strategies can be pushed and controlled by governments, cities, regions, and countries (macro level). At this step, the effort is shared by the entire community and the achievements can be measured by including all the actions undertaken by the society at both micro and meso levels.

Several actions and strategies should then be pursued to implement Circular Economy in manufacturing companies, ranging from the redesign of products and production processes to the exploitation of new business models and the establishment of a circular supply chain. Nevertheless, implementing one action alone ignores the **system perspective** that is central to CE and to the achievement of the intended sustainability benefits. For instance, increasing product life without altering the company's business model runs the risk of reducing its economic profitability, since product life extension will result in lower sales. Remanufacturing products that have not been specifically designed in a modular way might be difficult and economically challenging, because product dismantling and reassembly may take more time and effort (and hence involve greater costs). The expected environmental benefits of product reuse may be jeopardised by the absence of a proper and functional reverse logistics system since more transportation may be required.

Circular Economy challenges, best practices and the way ahead

Several economic, regulative, technical, organisational and behavioural **challenges** may prevent the implementation of Circular Economy in manufacturing companies and in their supply chains. Circular Economy solutions may be challenging from an economic and financial point of view, since they require large investments in R&D and in the conversion of production technologies. Despite some favourable legislation and regulations, sometimes current regulatory schemes risk hindering the introduction of Circular Economy models, especially if not appropriately designed. End-of-life activities involve several uncertainties regarding volumes, quality, and recovery times of collected products. The proper recycling of products is still challenging since the readiness level of several end-of-life technologies is still low. As an example, the Danish company, Lego, recently gave up its efforts to make bricks from recycled plastics due to complications with non-oil-based materials[117]. From a behavioural perspective, very often, circular products made with secondary raw materials are perceived as being of lower quality than new products, making it difficult to justify the higher price that is necessary to cover the higher R&D costs and treatments.

Although these challenges are still visible, several companies are embracing Circular Economy in their business models and inspiring the entire society to move towards circular approaches.

At the micro level, ABB[118], a technology leader in electrification and automation, aims to innovate their own operations with new circular business models for their customers. In 2022, they launched their EcoSolutions label, which provides full circularity on all their products. Their high-efficiency synchronous reluctance (SynRM) motors do not require rare earth metals for their production, but rather use low-carbon, recycled copper from 'Boliden' in their production. Using such copper reduces CO2 emissions by 200 kg per motor that weighs 650 kg.

PulPac[119], a Swedish company, has tackled the generation of single-use plastic (that contributes to 85% of marine waste) by developing an innovative 'dry-moulded fibre' product for the packaging industry. The production process involves almost no water with the product being completely biodegradable, having a low climate impact and high recyclability.

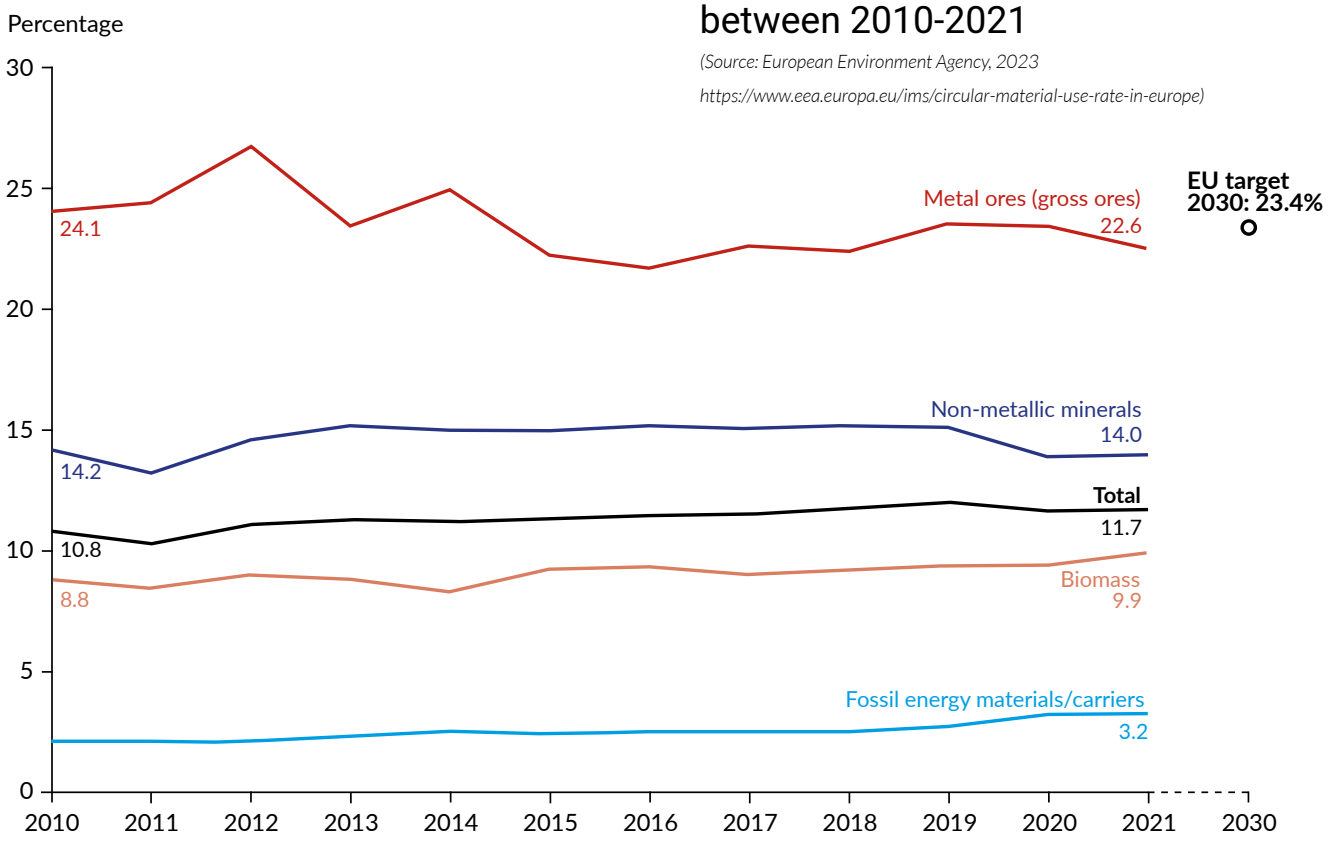
Fairphone[120], a Dutch company that develops modular phones with fair and recycled materials, takes responsibility for their material footprint by using 70% recycled materials in the manufacture of their phones. The modularity and easy disassemblability of their phones allow effective reparability and recycling. In collaboration with a German company called 'Teqcycle', they facilitate the resale and recycling of their phones through take-back schemes.

Many efforts have also been made at the macro level. To incentivise a cohesive movement of the entire society to reach their green transition objectives by 2050, the **European Commission** has set out ambitious targets for industries through the European Green Deal Industrial Plan[121]. Particularly, efforts such as the 'Circular Economy Action Plan', can help industries reach climate targets towards net-zero along with strengthening their competitiveness. The "Critical Raw Materials Act", which is a part of this framework, ensures that recycled critical raw materials for the development of net-zero technologies are available, to lower supply dependency from countries outside the EU and grow in the Circular Economy by reducing primary raw material consumption. Several investments have also been signed in this regard. Through the InvestEU programme, the EU has earmarked a total of €21 billion for projects that support this net-zero transition, including the recycling of critical raw materials. The Innovation fund will make available €40 billion to support the deployment of several technological solutions towards such efforts as well.
The EU aims to double its rate of circular material use by 2030 according to the Circular Economy Action

Figure 22

Critical material use rate in the EU between 2010-2021

(Source: European Environment Agency, 2023
https://www.eea.europa.eu/ims/circular-material-use-rate-in-europe)



Plan[122]. However, figures show that there was less than a 1% increase in this rate from 2010 to 2021 (Figure 22). Projections show that progress towards doubling the rate by 2030 will be slow and several incentives will have to be given if we are to stay on track towards this goal.

To be adherent to these objectives and plans, dispersed actions have been undertaken separately by several countries worldwide. Among all, it is worth mentioning the outstanding achievement obtained by **Italy** in terms of packaging recycled in 2023 that covers the objectives set to be achieved within 2030. Indeed, out of 14.5 million tons of packaging produced and used in 2022, 10.4 million were recycled[123]. Also, economic returns are possible; according to Ansa, 62% of companies that invested in circular economy projects have gained an increase in both profit and employment[124]. This result can be indirectly connected to recent research achievements like the one relating to the possibility of extracting rare earth elements during fertiliser production, which decreases the dependency on foreign countries[125]; and also that relating to the possibility of recycling composites, making them more cost-effective and environmentally friendly[126]. On the other hand, the **French government** has invested €154 million to support textile repair through the provision of discounts. In 2015, the **Czech Republic** invested in its waste management plan, and in 2019 it extended its efforts into building a secondary raw material policy that helped create an overarching framework towards sustainability[127].

A Success Story on Reshaping Your Manufacturing Business Model to Thrive in a Competitive Landscape

Andrea Ruotolo
PhD – Global Head Customer Sustainability, Rockwell Automation

Giancarlo Scaturchio
EMEA Customer Sustainability Manager, Rockwell Automation

State of play in today's industry

Manufacturing is a prime scene for innovative and disruptive business models. Value generation has shifted from being tightly coupled to tangible assets to increasingly relying on non-tangible value propositions such as digital services, data analysis insights, and platform integration, among others. This shift towards smarter and increasingly digital manufacturing is not only an option to increase previously product-dense offering portfolios, but their adoption will strongly influence, and even dictate who remains a player in increasingly competitive markets.

Many of the advances driving smart manufacturing in industrial settings are not all that new. Artificial intelligence, industrial IoT, additive manufacturing, and blockchain technologies have been accessible for several years and they have even been part of many technology companies' innovation roadmaps. In full awareness of many manufacturers getting trapped in pilot purgatory1, Rockwell Automation supports its customers to become a Connected Enterprise from Level 0 of Automation to the most sophisticated Cloud digital solutions. Through the evolution and adaptation of their working methods to fit customer's needs, they aim to support the shift to achieve digital trust, supported by digital threads and other traceability technologies.

The game changer in the most recent years lies in the increased interactions and interconnectivity between the technologies. Rockwell Automation's approach has relied on making the digital layer completely independent from the automation layer, enabling it to connect different data sources. In other words, new manufacturing environments are evolving not only due to technological adoption, but also because of how technologies operate together, share data, and engage in digital workflows that allow value capture.

The transition towards increasingly digital business models brings a more dynamic and lifecycle-focused approach to relationships between manufacturing end users, OEM builders, technology providers, and other actors in digital value chains. In this way, customers can obtain more value from their investments. However, it is worth noting that for digital business models to succeed, the concepts of scalability and security must be not only explored but dominated. Engaging in customer relationships where trust across partners predominates enables potential cost reductions, increased agility, and reduced time to market. Also, it avoids pitfalls where customers do not get the returns on investments that they expect.

Shifting from strong to stronger

Rockwell Automation is an industrial automation market leader, characterised by offering highly engineered hardware with embedded firmware that operates in often hostile industrial environments for long periods of time. In recent years, Rockwell Automation has responded to fierce market pressure by shifting from being a "pure play supplier" to including traditional products, lifecycle services, and manufacturing business consulting to support their clients on their digitalisation transformation. Rockwell has undergone this transition by incorporating "digital threads" into the company's hardware, expanding previously product-centred business models into software-as-a-service.

The logic behind this business model transformation can be summarised in three pillars:

- evolving the focus from physical products sold in catalogues to business outcomes and experiences.
- wholesale change in customer experience — not only in the way Rockwell customers procure and use Rockwell's equipment and services, but in tighter relationships to make industrial controls in a SaaS environment.
- developing a new business operating model and subscription-based services, reported as possibly the most challenging change.

The motivation behind this shift includes the appearance of new competitors in the playground of automation technologies, where large cloud-based firms have increased the availability of industrial clouds and services.

Clarissa A. González Chávez
PhD Candidate, Chalmers University of Technology

Competitors have marched into the market by enriching their traditional offerings with domain knowledge now tailored for manufacturing, among other sectors. Rockwell Automation has adopted a strategy where they establish a data-driven operating model mindset to expedite the transition to this customer-centric, data-driven, agile organisation. In its new as-a-service era, Rockwell now provides services both on the front end, such as partnering with customers on the design and development of customised hardware, and the back end, offering maintenance and cybersecurity of industrial controls.

Sustainability – The only possible North Star

Another large motivation for the transition of business models is Rockwell Automation's sustainability strategy, where sustainable customers, a sustainable company, and a sustainable community are the three pillars that act as a North Star for future developments. Rockwell Automation has made it its mission to make use of its ingenuous industry-focused approach to meet customers where they are and provide support to make use of their digital transformation as an accelerator to meet their ESG objectives. In doing so, they work towards diversity, equity, and inclusion to create opportunities that can be scaled to a more sustainable society.

The transition to digital, data-driven, and service-based business models has allowed Rockwell Automation to better develop its offerings to engage in conversations with customers about increased efficiency, reduced energy usage, improved worker safety, and ensured regulatory compliance. Some newly created examples include Sustainability Calculators, which offer a sustainability tool/dashboard where their customers can visualise the environmental impact of remanufacturing, motivating the transition from a linear to a more circular state of practice. In this offering, customers can easily access, track, and measure aggregate data on energy, water, waste, and CO2 emissions.

As for the challenges faced in this transition, Rockwell Automation, and other evolving firms face the need to identify and replenish a new set of competencies that many traditional manufacturing companies don't already have. In this sense, value co-creation and advice are required, which can take the form of consulting services, more frequent roadmapping, and more checkpoints.

In other words, although there are challenges on the horizon, the transition to new business models will continue to unlock many opportunities that reshape the future of industry and enable a more sustainable future.

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3

New Business Models for the Future of Manufacturing and How to Use Them

Digital Business Models

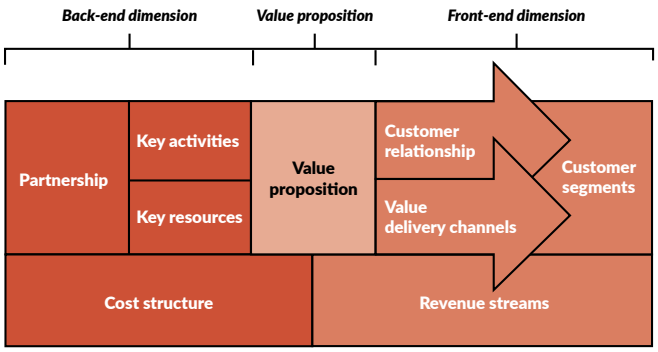
Defining digital business models in manufacturing

The advent of the digital economy and the subsequent advancements of digital technologies have generated many opportunities for business model innovation (BMI) in manufacturing companies. Just as IT companies like Facebook, Google, and Apple, manufacturing companies have also embraced digital advancements and implemented a continuous BMI approach to thrive in today's landscape instead of sticking to traditional business models (BMs).
The BM has been a useful lens for understanding a firm's business logic and value architecture. It describes how a company creates, delivers, and captures value[128]. Although different frameworks represent BMs, the Business Model Canvas is one of the most recognised in business practice[129]. It enables the analysis of companies' BMs by addressing nine elements (building blocks), which can be grouped into two main dimensions: back-end and front-end[130]. Figure 23 shows the BM Canvas and its dimensions and elements.

Figure 23

Main dimensions and elements of the Business Model Canvas

(Source: Marcon et al. 2022)

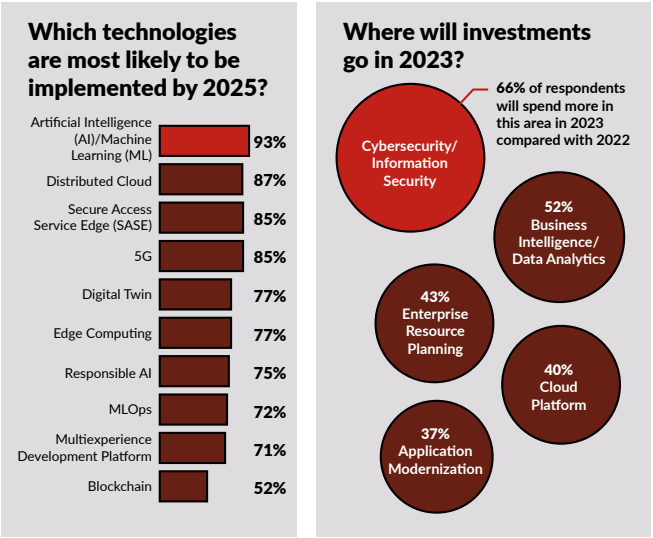


The back-end dimension encompasses the elements related to value creation, such as key activities (e.g. business processes), resources (e.g. capabilities), and the value network. On the contrary, the front-end dimension includes elements that deliver value to customers, such as customer segments, relationships with customers, and the marketing channels (distribution, communication, and sales) used to interact with customers. The value-capture elements encompass the costs associated with operating the business model, whereas revenue streams involve different ways of monetising business models. At the centre of Figure 23 lies the value proposition, which refers to the bundle of tangible and intangible offers (e.g. products, services, knowledge, performance, etc.) provided to customers.

Figure 24

Investments in digital technologies

(Source: Gartner, 2023)



The combinatory effects of digital technologies (e.g. data-based services), customer demands (e.g. customisation), environmental pressures (e.g. circular economy), and industry trends are[131] driving an increasing interest in BM architectures. In particular, technology has been a key driver of changes in value architecture. For example, a survey of manufacturing company CEOs reveals that 68% of the world's largest manufacturing companies are increasing their investments in digital technologies to promote BMI[132]. Another recent global survey published by Gartner[133] also identifies digital transformation as one of manufacturing companies' top three enterprise priorities. Figure 24 displays the digital technologies most likely to be implemented in manufacturing by 2025 and where investments have been directed in 2023.
These trends (Figure 24) demonstrate that manufacturing companies are shaping their future by undergoing the digital transformation of their traditional BMs, leading to new

Digital Business Models (DBMs). A BM can be categorised as 'digital' when digital technologies trigger novel and non-trivial changes in one or more key BM elements (Figure 23). In other words, the value proposition, value creation, and value capture are embodied in or significantly facilitated by digital technologies. For instance, digital assets and capabilities are critical for value creation; the value proposition shifts from physical to digital; digital platforms enable the development of more sophisticated offerings, and AI technologies mediate the customer interface. In short, DBMs are not a choice but a game-changer for manufacturing companies.

But how to recognise a DBM in manufacturing? DBMs generally differ from traditional BMs due to the following characteristics:

Smart products and services. Products have become more digitalised, intelligent, and integrated into different types of services (smart, digital, and traditional), forming a complete customer solution. The offer of product-service-software systems increases data availability and transparency, which drives new forms of value. For instance, ABB Ability™ and ABB Motion Services™ packages[134] combine knowledge, connectivity, and software innovation to provide tailored services, such as preventive maintenance and remote customer support.

Digitalised processes. Digitalising value creation and delivery processes enhances operational efficiency, quality, and customer experience. On the BM back-end dimension, digital twins create smart supply chains (allowing the exchange of information and integrating network actors), while AI improves responsiveness, resilience, and cybersecurity intrusion identification. Another example is the advances in smart manufacturing, in which Industry 4.0 technologies enabled by AI promote vertical integration within the factory. Digitalising marketing and sales creates more customer value on the BM front-end dimension. In this case, manufacturing companies have used advanced analytics and prescriptive insights for sales personnel, enabling them to provide personalised offers. An example of the use of digital channels comes from the automotive industry. In 2022, General Motors[135] launched an online parts marketplace, making its catalogue of 45,000 repair and maintenance parts more convenient.

Digital platforms. Although large platform companies dominate B2C markets (e.g. Amazon, Alibaba, or Uber), manufacturing companies seeking DBMs can rely on digital or multi-sided platforms to connect ecosystem actors and commercialise their value propositions. For instance, Siemens offers the Railigent platform within Siemens Mobility, empowering rail operators, maintainers, and asset owners to understand their railway data and generate valuable insights. This platform contributes to increased availability, improved operations, and reduced costs.

Ecosystem perspective. Over time, the ecosystem perspective has become more critical for manufacturing companies, as seen in vertically organised supply chains, service ecosystems, or multi-sided platforms. The ecosystem perspective, enabled by digital technologies, extends the boundaries of manufacturing companies and emphasises collaboration and value co-creation among other ecosystem actors.

Digitalisation is central to DBMs, and manufacturing companies are undergoing significant changes to implement one or more of the above characteristics. However, the transformational journey towards a DBM is difficult, complex, lengthy, and subject to friction, mainly for incumbent manufacturing companies in traditional industries. While digital-native companies' development of digital attributes (e.g. digital mindset, digital capabilities, or digital platforms) seems more organic and easier, incumbent manufacturing companies can face significant challenges in their digital transformation. The good news is that many digital incumbents have closed the gap and successfully executed a digital transformation, making the physical and virtual worlds meet.

In the next section, we discuss several DBM archetypes, while further on we present critical challenges in digital transformation and how to overcome them.

How manufacturers cope with digital transformation

Digital business models allow manufacturers to generate new forms of value proposition, value creation, and value capture. Following Müller and Buliga[136], three main forms of business models in manufacturing contexts can be distinguished: platform-based, outcome-based, and use-based business models.

Platform-based business models generate data from entire supply chains or industrial ecosystems. As a value proposition, they simultaneously serve multiple stakeholders and customers to offer the potential for optimisation across entire supply chains or beyond. Regarding value creation, platform-based business models are often based on data generated from Enterprise Resource Planning or Manufacturing Execution Systems. If these data stem from entire supply chains or industrial ecosystems, platform-based business models aim to generate Big Data from and for many stakeholders and customers. Therefore, the approach differs from the use-based or outcome-based business models described below. Typically, platform-based business models in manufacturing can only be established by larger companies or if several companies cooperate, but not by small and medium-sized manufacturers. This is since data generation on a large scale is required to run a platform-based business model. The value-capture mechanisms of platform-based business models are typically subscription or license models for the customers. An example is Siemens Xcelerator[137], which combines several Siemens products for multiple customers.

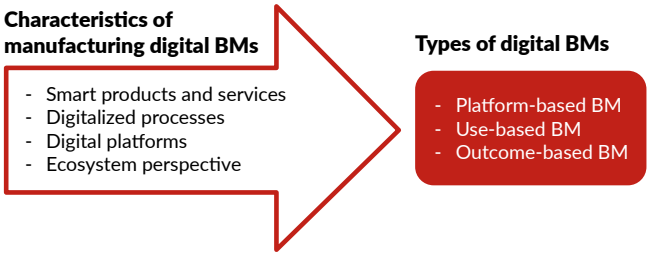
Use-based business models can be part of platform-based business models, like an add-on that is only paid for if used or represents independent business models. Use-based

business models are centred around data-driven value propositions. Those include value-stream analysis or real-time optimisation of production and logistics processes. Since those are highly specific and require additional value creation efforts, such as specific real-time sensor data collection and evaluation, they are typically combined with use-based value-capture mechanisms, i.e. those that are only paid for if used by the customer. An example includes German air compressor manufacturer Kaeser[138], which was one of the first to charge its industrial customers for compressed air rather than selling its compressors.

Outcome-based business models use value-capture mechanisms based on a value proposition with a clear benefit for the customer. Those include, e.g. the reduction of downtime and improved Overall Equipment Effectiveness within a manufacturing cell or improved product development processes. Since their value proposition is based on an actual and often specific benefit for the customer, the value-creation process is also based on specific data collection and analysis. Typically, value propositions like data evaluation and analysis are combined with specific services, such as implementation, consultancy, and process optimisation. For many Small and Medium-sized Enterprises or firms not present on typical industrial platforms, outcome-based business models present a niche in which they can prevail while preserving their specific customer base and retaining their customer contact. As for use-based business models, outcome-based business models can be added to platform-based, or combined with use-based business models. An example of an outcome-based business model is Hitachi[139], which charges customers for cost cuts or better performance, among other examples. The main characteristics and types of digital business models used in manufacturing are visualised in Figure 25.

Figure 25

Characteristics of digital business models and different digital business model types in manufacturing



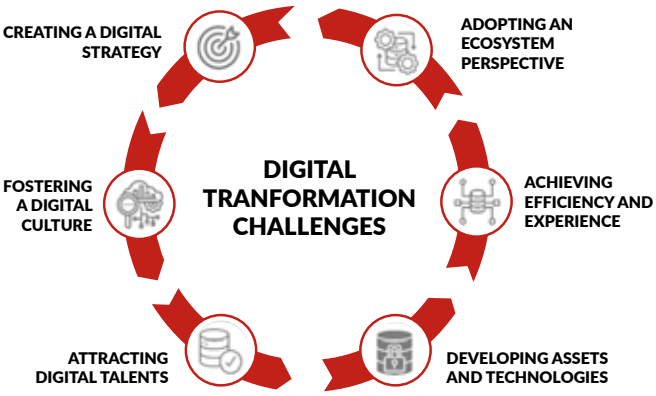
Challenges and opportunities for digital business models in manufacturing

A recent survey by Deloitte[140] encompassed more than 800 participants at the C-level and BU-head levels of four industry sectors (automotive, machinery, chemicals, and pharmaceuticals). The results emphasise that digitalisation remains the primary focus of investment for the companies, with around 30% expressing their desire to accelerate their digitalisation efforts.

However, digital transformations are challenging, and manufacturing companies must overcome several challenges to increase their chances of success. Figure 26 shows some critical challenges.

Figure 26

Digital transformation challenges

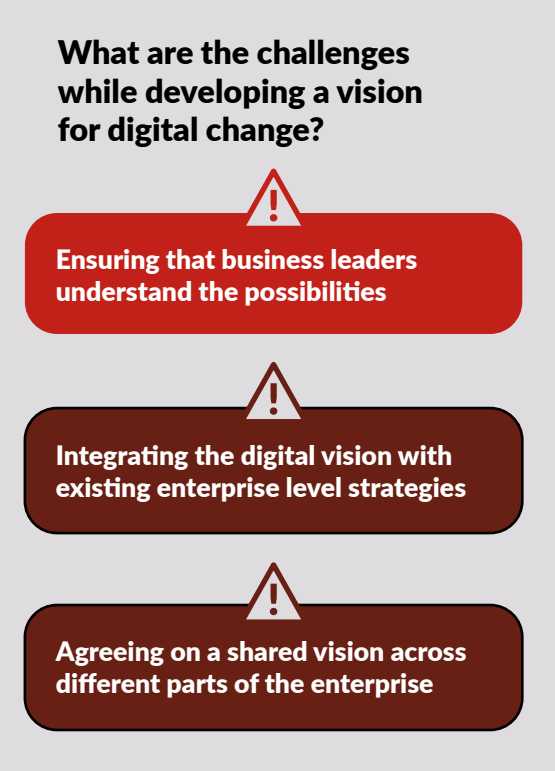


The first challenge is to develop a digital strategy, since it guides and creates a vision for manufacturing companies pursuing their digital transformation journey[141]. To create a robust **digital strategy**, companies need a deep understanding of digital trends, a thorough analysis, and close collaboration across the entire organisation and its ecosystem. As shown in Figure 27, the main concerns in creating a digital strategy are the lack of understanding of the potential value of digitalisation or the need for change, how to integrate digital strategy and other companies' strategies, and how to ensure that different units understand and are aligned with the digital strategy[142]. Another challenge revolves around developing an **innovation culture** that fosters customer-centric values, embraces a digital mindset, encourages a willingness to experiment (test-and-learn cycles and risk-taking initiatives), and the adoption of metrics and incentives tailored to monitor and recognise digital initiatives. Aligned with digital strategy and innovation culture, the company´s capacity to attract and retain **digital talents** has emerged as a critical factor distinguishing businesses that have fully embraced DBMs from those that have not.

Figure 27

Digital strategy development concerns

(Source: Gartner, 2023)



Challenges for digital transformation are often attributed to missing digital capabilities in data generation, transfer, and analysis. This is especially true for traditional manufacturers with high competencies in mechanical properties but lacking digital competencies. Even more, small and medium-sized enterprises (SMEs) or traditional industries are struggling with scaling up data competencies[143]. Further, non-technical factors include the customers' success in the implementation process and the generation of value-capture mechanisms that customers can accept. Further, organisational change processes typically challenge established industrial manufacturers that are, however, required to transform from a manufacturing business model to a digital business model in manufacturing. This includes organisational resistance, unclear responsibilities, or missing competencies[144].

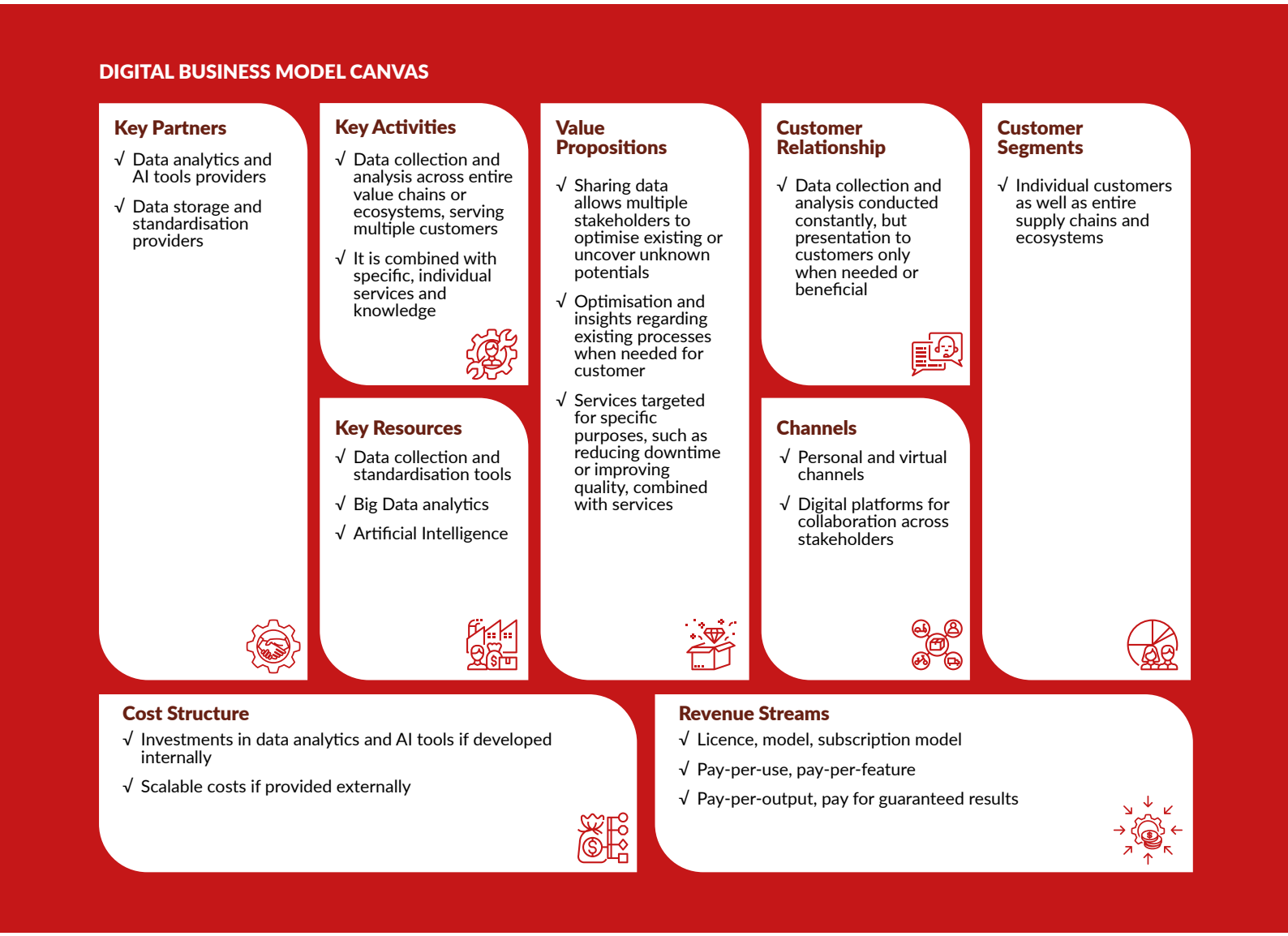
Another challenge is developing digital assets and platforms that offer agile, scalable operation and collaboration with external partners. As shown in Figure 26, technologies like cybersecurity, AI decision support, SASE, 5G, and cloud platforms are particularly interesting. Therefore, manufacturing companies must invest in several core technologies and digital assets to achieve digital maturity.

Further, it must be noted that digital business models fail for many industrial companies. As a prominent example, the attempts of General Electric (GE) to launch a digital business model failed due to a lack of customer demand and not generating revenues, among other factors[145]. Hence, customer demand and alignment with their requirements is a challenge, as well as generating operational efficiency with a digital business model[146].

If digital business models are implemented in industrial ecosystems, the combination of the platform concept and ecosystem concept bears additional multiplying factors, such as multi-sided business models for multiple customers, including new customer groups. Still, governance of an ecosystem, generating sufficient (data) volume on a platform, and potentially too many companies aspiring to run the ecosystem rather than benefit from it are among the most prominent challenges[147].

Regarding the **opportunities for digital business models** in manufacturing, many established manufacturers can now offer new forms of value proposition in which a physical product is accompanied by digital services, thus enhancing the existing product. Examples include predictive or condition-based services, or optimisation and implementation services[148]. In value creation, manufacturers can use the data generated to optimise their products and their customers' manufacturing environments where those are used. However, especially the value creation of digital business models comes with the challenges above for traditional, established manufacturing firms.

Finally, value-capture mechanisms allow manufacturers to generate value out of quality that customers were willing to pay for indirectly, but which could not be monetised before. For instance, the promise of a machine that allows fewer downtimes and failures over a long period is appreciated by many customers. However, many customers struggle to quantify this promise. Thus, a better machine might be even more expensive, so fixed costs are much higher, preventing its purchase from a controlling-driven logic. However, if the digital data of downtimes and availability allow the above-named use-based and outcome-based business models, customers pay for what they get. Thus, quality can be sold not by higher sales prices, but in the long run with customers paying for clear outcomes or using individual services to their benefit.



Data-Driven Business Models

In the digital age, manufacturing is undergoing a profound transformation, driven by data and technology. In this section we explore the impact of data-driven business models on the manufacturing industry, using the Business Model Canvas as a lens to compare traditional and data-driven approaches.

The Business Model Canvas comprises key elements like internal value creation, external value creation, key resources, key activities, and key partners, which are now evolving in the context of data. The aim of this section is therefore to delve into how data are redefining manufacturing processes, customer interactions, and the roles of critical resources and partners.

The goal is to shed light on the data-driven manufacturing landscape, showcasing how data are revolutionising the industry. The contrasting features of traditional and data-driven models will be highlighted, emphasising data's role as the catalyst for innovation and efficiency in manufacturing.

In the following paragraphs, business model components will be analysed in detail, offering insights into the transformative possibilities of data-driven manufacturing.

Value creation 'external view'

The "ability to monetise data effectively — and not simply hoard it — can be a source of competitive advantage in the digital economy[149]".
It is important to emphasise that substantial data volumes are no longer a distinguishing factor in the realm of manufacturing and production. Data have been an integral

aspect of the manufacturing landscape for decades. Yet, despite the progress in harnessing data and the fact that modern machinery now comprehensively captures data, the primary focus has often remained on optimising internal processes and decision-making procedures. The potential of these actions should not be underestimated. They often provide a good entry point, form a basis for successive action and will continue to be highly relevant. Nonetheless, these internal process improvements may become a hygiene factor and it would be desirable not to stop at this point to really exploit the potential of data-driven manufacturing.

Looking ahead, manufacturing enterprises should increasingly divert their attention towards effectively leveraging and translating data into marketable offerings. This entails the creation of new innovations driven by data. These innovations may closely align with existing core products and services or pave the way for entirely novel business models and revenue streams.

The possibilities for integrating data into products and services are extensive and multifaceted. Asset monitoring, early detection and prediction of potential errors, remote support or fleet management dashboards are common offerings. Further connecting and gathering data from a machine provides the necessary transparency and enables new service-oriented business models, such as performance-based guarantees or secured availability (pay-per-use, outcome-based contracting). Without real time operational data and log-files, these models are often opaque and pose risks, leading to challenging negotiations when problems arise or render these models impossible.

Taking it a step further, when considering autonomous systems, data become the foundation for securely managing processes and workflows. Data serve as the communication medium between actors that no longer necessarily require human interaction but, as a counterpart, requires an even more structured and robust workflow. If errors occur in data acquisition, transmission, or interpretation, it can result in high failure rates, decreased efficiency, or even the collapse of entire process chains. As data-driven offerings in this context will have an overarching and profound impact on complete value chains, and different organisational boundaries are crossed, companies have to find their position in emerging ecosystems.

The car manufacturing business can be used as an example since it is an industry which will be transformed when autonomous driving becomes reality. Data-driven offerings might range from matching passengers and cars on mobility platforms up to highly personalised customer experiences. New market participants and disruptors might enter the mobility market as operators of autonomous fleets and intermodal-mobility concepts. The gathered data from car operation might be useful for fleet optimisation but also for other external offerings, like road surface quality detection services which can optimise road maintenance processes of municipalities[150].

To approach the topic of new value propositions, established frameworks can help for orientation. Answer the question of whether companies offer a promise to assist a customer (input) or to guarantee a performance (output). Does the offering relate to the product or to the larger process in which a product is embedded[151]? Other options might be the strategic choice to operate as a platform orchestrator and build an ecosystem or an integrator within existent ecosystems.

There is no golden path to follow for a successful transformation journey with data-driven offerings. But, amidst all the technological possibilities, it is important to ensure that the offerings deliver value to customers. Further offerings should align with the company's overarching strategy, justifying the investments and efforts required for the necessary infrastructure.

Value creation 'internal view'

Historically, the process of production lacked transparency. Requests for purchases were sent to the manufacturing team, and the resulting finished products seemingly materialised without clear and detailed understanding. In complex production setups that entail various stages of value creation, production managers may encounter difficulties in comprehending the intricacies of the processes involved. Nevertheless, it is imperative for them to have a comprehensive understanding of all aspects related to production to guarantee the highest level of efficiency and output.

Organisations can significantly benefit from utilising data in their production processes. By doing so, they can achieve greater transparency and gain a deeper understanding of how value is created. This can ultimately lead to more informed decision-making and improved overall performance by transitioning to a Data-Driven Business Model (DDBM). In a theoretical world where manufacturing companies not only produce goods but also cultivate a seamless and innovative process, data act as a guide, deftly directing each step of the production process towards a successful buildup.

On the manufacturing floor, data go beyond mere numbers; if correctly managed and used, it is the tool that unlocks the possibilities of creativity and efficiency. With data as the guiding force, every aspect of the manufacturing process is elevated to a new level of precision, accuracy, and ingenuity. The result is a truly seamless and innovative process that sets the standard for manufacturing excellence.

Companies in the manufacturing industry that utilise data as a crucial component can attain optimisation by meticulously refining each process. The powerful insights offered by data expose and eliminate bottlenecks, diminishing inefficiencies. Quality controls guarantee that every product produced conforms to the required

standards. By leveraging real-time data, defects are quickly identified and rectified before they even have the chance to manifest.
The management of inventory through data ensures minimal wastage and cost reduction, utilising every resource to its fullest potential and pursuing maximum efficiency.
Sustainable manufacturing practices rely heavily on the efficient use of energy. By analysing data, manufacturers can identify areas where costs can be reduced while also benefiting the environment. The careful allocation of resources is central to achieving maximum value, with labour, capacity, and materials working in perfect harmony.
To succeed in today's data-driven manufacturing landscape, innovation is key. By pushing the boundaries of product development, manufacturers can reach new heights and exceed expectations. Supply chains, too, require new levels of adaptability and responsiveness, where market changes are quickly addressed, and value creation remains at the forefront.
A culture of continuous improvement is vital in the manufacturing industry, with team members empowered to seek out opportunities for optimisation and innovation. In this world, data are more than just information; they must be used to set direction, resonating far beyond the factory floor and creating value that exceeds expectations.
The Siemens plant in Chemnitz, known as Siemens WKC, is pioneering data-driven manufacturing to achieve significant cost reductions in control cabinet production. They are leveraging digital-twin technology and AI systems to enhance automation over the next decade, ultimately aiming for autonomous assembly processes. This strategic shift is driven by the imperative to realise cost-efficiency and resource savings while maintaining a high degree of flexibility to meet evolving market demands.

Key Resources

The transformative changes in manufacturing are closely tied to shifts in key resources. Embracing these changes and aligning resources with evolving market dynamics are critical for manufacturers to remain competitive and capitalise on emerging opportunities.

Manufacturers are heavily investing in their infrastructure, embracing advanced technologies like cloud-based computing and edge computing. This influences a manufacturer's ability to handle vast data volumes efficiently and provide real-time insights, which can be leveraged to create new value propositions or gain internal process optimisations. Especially for new value propositions, it is often crucial to build up domain knowledge about the usage face. This is often lacking because manufacturers often do not have data, nor vast experience of the operation of built assets.
For data-driven business models, the workforce will further change because new capabilities are needed. Also, software development and data literacy can be outsourced to a great extent; organisations should also build up their own capabilities to avoid excessive dependencies. In industries such as aerospace, this resource might help to enhance product design, contributing to improved performance and safety.
Last but not least, balancing data sharing with data protection is essential. This involves managing intellectual property while engaging in collaborative efforts. Intellectual property protection is a key resource. In the pharmaceutical industry, for example, it safeguards valuable drug formulation data.
Examples for changes within the key resources on the transition to data-driven manufacturing is, for example, Hyundai, heavily investing in their transformation to a smart mobility solution provider (i.e. acquisition of 42dot and Boston Dynamics), or Siemens building up its digital team with Siemens Advanta and also acquiring new resources (i.e. Vendigital).

Key Activities

When it comes to adopting a Data-Driven Business Model in the manufacturing industry, data play a crucial role in driving transformation and creating business value. It is not just a collection of information, but rather a source of inspiration for innovative ideas and endless potential.
According to the data information knowledge wisdom (DIKW) model[152], information is only truly useful when it is presented in a way that can be effectively utilised, recognised, decoded, and evaluated by individuals. Knowledge, on the other hand, is derived from experience gained through the use of information, often as a result of interactions between two or more individuals. The DIKW model provides a clear hierarchical order that demonstrates the progression from data to information to knowledge to wisdom. The ongoing debate surrounding the definitions of data, information, knowledge, and wisdom underscores the importance of tailoring information to the specific needs and interests of the user in order for it to be valuable. Ultimately, the customisation of information is essential in enabling individuals or organisations to solve problems in a meaningful way.
The process of collecting data is the starting point for a complex and meaningful composition. Various sensors and technologies gather fragments of information, which are then used to create a foundation of understanding.
Data integration allows the bringing together of different sources of data to create a comprehensive overview of a problem. It ensures that all the different aspects are considered, and that strengths and weaknesses are properly addressed.
When properly performed, data analysis allows for the decoding of complex problems and identification of the root causes of problems. With the help of predictive

analytics, machine learning, and statistical techniques, it transforms raw data into information and knowledge that can be used to overcome challenges and can be reused in other contexts.
The importance of data security and compliance cannot be overstated, as they are integral to maintaining the integrity of data. On the other hand, customer insights and market intelligence serve as valuable tools that provide feedback on consumer behaviour, preferences, and trends. By leveraging this information, businesses can make informed decisions and shape their direction accordingly. It is crucial for organisations to prioritise both data security and customer insights to remain competitive in today's market.
CatenaX serves as a platform provider for data-driven manufacturers, empowering them to participate in key activities within the automotive industry supply chain. Developed by the German Association of the Automotive Industry (VDA), CatenaX offers a digital ecosystem that facilitates transparency, traceability, and efficiency across manufacturing processes. It enables manufacturers to seamlessly engage in activities such as real-time data sharing, traceability of components, process optimisation, and sustainability efforts. By offering this digital infrastructure, CatenaX empowers manufacturers to embrace data-driven approaches and enhance their operations in the automotive sector.

Key Partner network

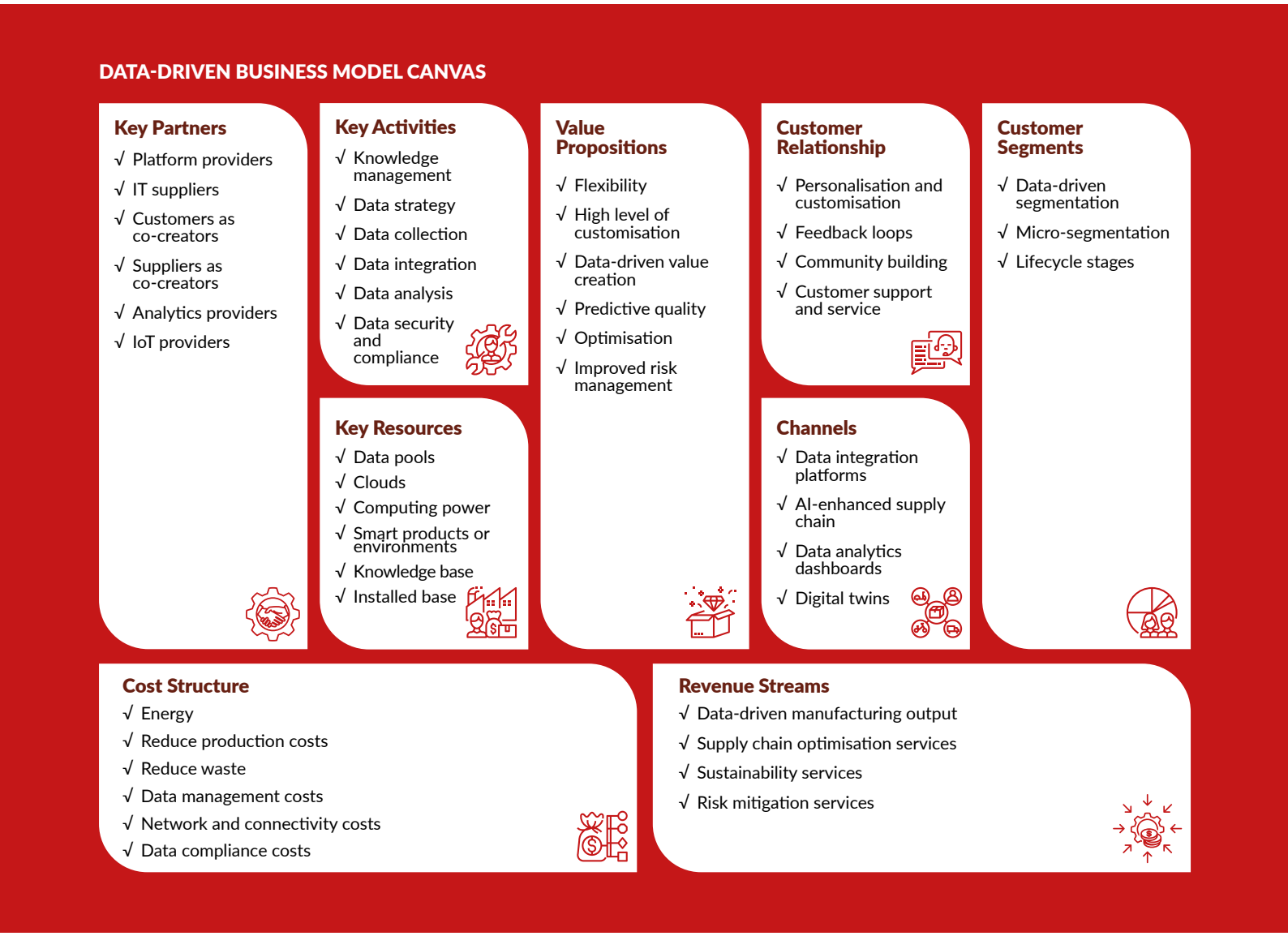
Establishing a robust partner network is essential for manufacturers aiming to harness data-driven business models across various industries. Key considerations include collaborating with technology partners specialising in data analytics, artificial intelligence (AI), and the Internet of Things (IoT) to effectively leverage data. Additionally, forming partnerships with data providers can provide access to external data sources that complement internal data, enhancing insights and decision-making. Manufacturers should also work closely with suppliers and supply chain partners to optimise production processes and gain visibility into their supply chain, leading to improved efficiency and responsiveness.
Research and development institutions, including universities and innovation centres, offer valuable opportunities for collaboration, allowing manufacturers to tap into cutting-edge research and talent. Engaging with government agencies and industry regulators is crucial to ensure compliance with data privacy and industry-specific regulations. Moreover, participation in industry-specific ecosystems or consortiums enables manufacturers to share best practices and insights with peers while staying updated on industry standards.
For a concrete example in the automotive industry, car manufacturers like Ford have partnered with technology companies such as NVIDIA to leverage their AI-powered solutions for autonomous driving. This collaboration equips Ford with advanced AI capabilities to enhance autonomous driving features, illustrating how technology partnerships can drive innovation and competitiveness. Furthermore, manufacturers like GM have joined forces with Google, leveraging Google Infotainment System and Services to enhance customer experiences. This strategic partnership enables GM to harness data for a more personalised customer journey, illustrating the importance of data-driven partnerships in the automotive sector's transformation. Another interesting collaboration is the case of Trumpf and Relayr, a MunichRe company where an OEM and an insurance company collaborated in the field of innovative, risk-based business models in the form of equipment-as-a-service.

Future strategic focus areas

The grand challenges of the future will force organisations to work more closely together. Existing industrial logics are increasingly being challenged and even if the manufacturing industry has recently mastered past crises and disruptive changes, geopolitics, climate change and the evolution towards Industry 4.0 will demand even greater adaptation and transformation.
Recent studies show that data-driven companies are better able to meet these challenges[153]. But this may come at a high price. Embracing advanced manufacturing technologies and Data-Driven Business Models presents a significant opportunity for the manufacturing industry. These innovations not only enhance competitiveness but also enable proactive compliance with future regulations. This requires companies to reposition themselves, to change deeply rooted organisational cultures and mindsets but also to re- and upskill existing employees to offer more sustainable and competitive data-driven value propositions through their evolving partner ecosystem, built-up resources, and new activities.
Nevertheless, the efforts in the transition towards DDBMs is promising and might be used as a base to innovate and improve in different areas:

- Data-driven innovation of existing product and service portfolios.
- Decarbonisation efforts and traceability within the supply chain.
- Operational excellence and cost-efficient manufacturing.
- Enhanced customer experiences and business models enabled by data-driven insights and self-optimising autonomous systems.
- Enabler for many business models (i.e. Circular Economy, Servitisation, AI).

Even if the future cannot be clearly predicted, companies and decision-makers must ask themselves the strategic question of what role they would like to/could play in such a scenario in order to derive fields of action.



AI-based Business Models

AI regulations impacts on AI-based business models

AI regulation refers to the set of rules, laws, and policies that governments and regulatory bodies put in place to govern the development, deployment, and use of artificial intelligence (AI) technologies. Currently, in 2023, there are no such mandatory regulations on the usage, training, or deployment of AI models. There have been numerous guidelines published to support ethical AI development and implementation, but few government-enforced rules. However, this is a growing trend, and the situation is therefore likely to change in many countries in the near future. The goal of AI regulation is to ensure that AI systems are developed and used in ways that are safe, ethical, and compliant with legal and societal norms. Key aspects of AI regulation are ethical and safety standards, data privacy and security, liability and accountability, certification and testing, transparency and explainability.

More regulatory laws will be enforced in multiple countries in the near future, following action being undertaken in the EU, Japan[154], and the US[155]. The Artificial Intelligence Act (AI Act)[156] by the European Commission classifies AI models into different risk levels. Unacceptable, High Risk, Limited Risk, and Minimal Risk.

Unacceptable: these AI systems will be banned and can't be certified. Examples are applications that pose a clear threat to safety or livelihood. Also, all social scoring systems used by public authorities are strictly prohibited. Also prohibited are any real-time remote biometric identification systems used by law enforcement in publicly accessible spaces.

High Risk: these include applications related to transport, education, employment, and welfare, among others. Before putting a high-risk AI system on the market or in service in the EU, companies must conduct a prior "conformity assessment" and meet a long list of requirements to ensure the system is safe. Requirements are, for example, adequate risk assessment and mitigation systems, high quality of the datasets feeding the system to minimise risks and discriminatory outcomes, logging of activity to ensure traceability of results, detailed documentation providing all information necessary on the system and its purpose for authorities to assess its compliance.
Limited Risk: these refer to AI systems that meet specific transparency obligations. For instance, an individual interacting with a chatbot must be informed that they are engaging with a machine so that they can decide whether to proceed (or request to speak with a human instead).
Minimal Risk: these applications are already widely deployed and make up most of the AI systems we interact with today. Examples include spam filters, AI-enabled video games, and inventory-management systems.

What does it mean for AI-based business models?

A large survey of 100+ AI start-ups has been conducted concerning the impact of the AI Act on business models[157]. Of the 113 EU-based AI start-ups, 33%-50% of the AI Systems would classify as High Risk. The findings of the survey are as follows: now being somewhat competitive, most of the 15 surveyed Venture Capitalists expect that the AI Act will drastically reduce the competitiveness of European start-ups in AI. For "High-Risk" AI Systems, the additional requirements and obligations are a significant challenge for start-ups in terms of technical and organisational complexity and compliance cost. Venture Capitalists investments shift towards AI Systems with a specific purpose, in low-risk applications, and, to some extent, to non-AI start-ups and outside Europe. A study by the Center for Data Innovation[158] concluded that the AI Act would cost the EU Economy €31 billion over 5 years, since it is the most restrictive regulation and the earliest.

What does it mean for AI-based business models in the manufacturing domain?

Various databases for use cases of AI systems and their risk category classification are being developed. Of 106 AI Systems in the Risk Classification Database by appliedAI Initiative[159 160], the majority of the manufacturing use cases such as quality control or process control and optimisation are categorised as low risk. This is largely because the AI system is not a safety component, as it is intended to control the quality of produced parts. It does not affect the safety of the pressing machine. The Predictive Maintenance use case has an unclear risk category evaluation. It depends if the maintenance of a machine is considered safety critical, because it has no component itself, but a failure of maintenance may be safety critical.
The primary responsibility of certification and regulatory compliance will be shouldered by the 'providers' of AI systems. Certain responsibilities will also be assigned to distributors, importers, users, and other third parties, impacting the entire AI ecosystem.

AI-based business model structure

Customer Segments

The AI-based business model creates value for literally all relevant organisations in the manufacturing industry, including original equipment manufacturers, third-party suppliers, supply chain actors, and other stakeholders in the industrial ecosystem. Different customer segments perceive different values for different objectives through different specific AI-based business models. Noticeably, the customer segments included here are described generally, but the labels become more specific considering the specification of use cases.

Value Propositions

In general, newness and innovativeness are the main values that customers prefer to acquire when introducing a novel business model (Metelskaia et al., 2018). Specifically, adopting AI-based business models can reduce costs. For example, implementing machine learning algorithms can enable better optimisation of product design at the product level and, at the system and process level, of not only production planning and scheduling but also the usage and allocation of resources, such as raw materials, human resources, operational technologies, and energy consumption. AI-based business models can also enable better forecasting of market demand so that manufacturers and other stakeholders within the manufacturing system can calibrate their business accordingly, which may further contribute to cost reduction. The superiority of AI techniques in state analysis and future prediction also enhances the reliability and availability of manufacturing systems by enabling prescriptive analysis or risk mitigation and proactive issue resolution.
Besides, AI-based business models can facilitate achieving better user experiences with mass customisation or curation for tailored experiences enabled by better and more objective analysis of customers' needs. Implementing AI technologies in customer services can also strengthen the connectivity between businesses and customers with the remote customer connection by enabling remote assistance by AI alongside human experts. The connectivity among existing systems can also be strengthened with AI-based business models implemented.

Channels

Overall, products and customers can be mutually reached through direct access and indirect access. For direct access, AI-based products or services can be delivered from providers to customers directly through variant channels, such as application stores, applications on specific platforms (e.g. Microsoft Azure, Amazon AWS, PTC, Bosch), AI model repositories, pre-trained AI models in a Model Zoo. Customers can find and download AI-based products or services through these channels. Providers can also provide AI-based products or services by pre-installing or preconfiguring them in equipment. For indirect access, a third party is involved in the channel where the third party integrates AI-based products or services into their own products or services, for example, by API integration or through API calls, and then provides their products or services to customers.

Customer Relationships

The customer relationships segment is revolutionised with diverse strategies tailored to the digital age to create a seamless customer journey. AI-based self-service becomes feasible for users to better navigate independently, such as 24/7 Personal Assistance by chatbots ensuring constant intelligent support, and automated service optimising efficiency. AI-based business models will also foster online connectivity, with the virtual community better informed, and encourage collaboration through enhanced co-creation. Hyper-personalised delivery, driven by complete customer data, is complemented by intelligent loyalty or reward programmes for sustained engagement.

Revenue Streams

The AI-driven business model includes direct selling of AI-related assets for immediate income. Usage fees align costs with service value, subscription fees offer recurring revenue, and licensing ensures controlled AI technology use. Additionally, data monetisation and consumption-based pricing maximise earnings from valuable insights and tailored service usage.

Key Resources

In the AI-based business model's infrastructure, key resources like robust computing power, extensive data storage, and specialised processing units that drive physical/hardware capabilities are essential. The software suite includes essential tools for model management, user interaction, monitoring, and adaptable operating systems. Skilled human resources are vital for setup, maintenance, customer service, and software customisation. The business model thrives on a dynamic data-based ecosystem, fostering ongoing innovation and adaptability.

Key Activities

The key activities are the strategic vision and planning beforehand. This includes the use case identification, modelling, and deployment. Typical AI-based use cases in manufacturing are quality/anomaly detection, predictive maintenance, and system optimisation. Use cases can be grouped into three categories. The system level, the workstation level, and the process level.
The modelling activity contains all AI technology aspects. The solution design includes resources, algorithm selection, feature engineering, and feature selection. After design considerations have been taken into account, prototyping and proof of concept of the AI system can take place. After the modelling phase, the key specifications are set. The system has a clear objective and the data and algorithm used to reach the objective are specified. Additionally, it is shown in the prototype that the solution is feasible, and predictions are accurate enough for the use case in question.
Deployment: in the deployment activity the model is integrated into operation. Issues here are the scalability, the integration with existing business processes, and model management (revisioning, monitoring).

Key Partners

The partners involved in the business model can be grouped into different roles/stakeholders in the ecosystem. The roles are: Technology Provider, Service Provider, and Solution Provider.
Technology Providers are needed during the building and developing phase. Typical AI technologies needed are: data science platforms, integrated development environment (IDE), development kits, libraries, and bundles. These technologies are provided by either a foundation, large tech companies, or open-source developers.
Service Providers are needed during the operation phase. Here, a hosting service such as a platform or cloud operator is essential. Additional service providers are security services, regulatory services, financial services, and marketing services.
Solution Providers help as strategic partners for business aspects or as a holistic partner. Solution providers can be software development firms, AI consultancy firms, AI start-ups, or AI research institutes and hubs.

Cost Structure

The most important inherent costs of an AI-based business model are Human Resources in the form of AI specialists, hosting costs for model operation and execution, R&D for model improvement, scaling infrastructure, data security and legal compliance, licensing costs, and large data acquisition and management.

Deployment of AI models in manufacturing

There are various ways to deploy an AI model, depending on the specific requirements of the project, the infrastructure, and the deployment target system. AI systems can be designed with local deployment or cloud deployment. Local deployments are on-premises servers, desktop/mobile applications, deployment on edge devices, or directly on operational technology (OT). Cloud deployment is typical for web applications. Here the AI model is deployed on large cloud providers such as AWS, Azure, and Google Cloud or smaller IoT platforms.

Deployment on OT hardware such as programmable logic controller (PLC) of, for instance, machine tools offers the advantage of low latency and higher security. These stricter requirements are necessary for real-time process control applications. Web Applications, on the other hand, are used for less time-critical use cases.

Deploying these models has become easier recently due to prefabricated deployment pipelines, and integration in the regular Continuous Integration/Continuous Deployment (CI/CD) pipeline. These new MLDevOps pipelines integrate AI model deployment into your CI/CD pipeline and fully automate the process of deploying new AI models onto target systems[161]. Higher standardisation has also reduced the effort during deployment. For instance, the Neutral Exchange Formats such as Predictive Model Markup Language (PMML)[162], Neural Network Exchange Format (NNEF)[163], and Open Neural Network Exchange (ONNX)[164] have addressed the challenge of the different frameworks used during development and deployment. ONNX is an open format which has been in development since 2018, originally initiated by Microsoft, Amazon, Facebook, and additional partners. It is very versatile and has high compatibility with development and target systems.

In conclusion, the key characteristics of the AI business model are the unique use cases of AI in manufacturing and their inherent large potentials such as increased operation efficiency, energy savings, and robustness. The main recommendations are to adopt the technology strategy or alter the existing strategy to incorporate new business models and timely compliance with upcoming regulatory aspects. The overall outcome estimates should be realistic and not driven by current AI hype.

AI-BASED BUSINESS MODEL CANVAS

Key Partners

Technology Provider:
- √ Data science platform / IDE / development kits / libraries / bundles
- √ Foundations / large tech companies / open source developer / libraries supplier...

Service Provider:
- √ Hosting service (platform / cloud operator)
- √ Security services
- √ Regulatory services
- √ Financial services
- √ Marketing services

Solution Provider:
- √ Software development firms
- √ AI consultancy firms
- √ AI start-ups
- √ AI research institutes and hubs
- √ Software-as-a-service (SaaS) companies
- √ AI as a service

Key Activities
- √ Strategic vision and planning
- √ Use case identification
- √ Data strategy and management

Modeling:
- √ AI technology / resource / algorithm selection
- √ Feature engineering
- √ Feature selection
- √ Prototyping and proof of concept

Deployment:
- √ Scalability, integration with existing business processes
- √ Revisioning
- √ Monitoring (model drift) and optimisation

Key Resources
- √ Physical / hardware
- √ Software
- √ Human resources
- √ Dynamic data-based ecosystems

Value Propositions
- √ Newness
- √ Innovativeness
- √ Cost reduction
- √ Connectivity enhancement
- √ Reliability enhancement
- √ Availability enhancement
- √ Better user experience

Customer Relationship
- √ AI-based self service
  - Personal assistance 24/7
  - Automated service
- √ Virtual community
- √ Enhanced co-creation
- √ Seamless customer journey
- √ Hyper-personalised delivery
- √ Loyalty programmes / Reward programmes

Channels
- √ Direct access (app stores, Model Zoo, pre-installed / pre-configured with the equipment
- √ Indirect access (API-integration / through API calls)

Customer Segments
- √ Manufacturing companies
- √ Original equipment manufacturer
- √ Third party supplier
- √ Supply chain actors
- √ Stakeholders in the industrial ecosystem
- √ Other AI business models (interaction b/w machines)

Cost Structure

Revenue Streams

Mass Customisation Business Models

Mass customisation, as a new business model for the future of manufacturing, stands in stark contrast to the traditional standardisation of mass production. However, as described in the relevant section of Chapter 2, "Mass customisation economy", there is no 'one-size-fits all' business model for mass customisation. Rather, a variety of successful mass customisation business models can be developed that exploit and transform heterogeneous customer needs into profit, while meeting the needs of society now and in the future. Moreover, mass customisation can be considered as a strategic mechanism along the entire value chain of a company; from product or service design to the manufacturing processes and finally to the usage phase.

Following the logic of the Business Model Canvas, shifting from a standard business model to a mass customisation-based business model could imply potential modifications at every element of the Canvas. In a first overview, we portray rather generic potential changes. Subsequently, we outline specific conditions and requirements that enable a profound business model transformation and (can) support the success of mass customisation: 1. reconfigurability and modularity, 2. agility and 3. sustainability.

Generic modifications for implementing mass-customisation business models

Customer Segments

Mass production typically targets broad and homogeneous market segments. In contrast, mass customisation focuses on narrow and highly segmented customer groups or even individual customers. The goal is to cater to the diverse preferences and needs of each segment, offering personalised solutions that resonate with individual buyers.

Value Proposition

The value proposition in mass production centres around cost-effective, standardised products designed to serve a mass market efficiently. Mass customisation, on the other hand, places a strong emphasis on delivering tailored and personalised solutions that align with the specific requirements and desires of each customer. It offers a unique value proposition that goes beyond the one-size-fits-all approach. Particularly in B2C markets, the I-designed-it-myself effect leads to additional value being ascribed to the mass customised solution.

Channels

Mass production relies on traditional retail channels where a limited range of options is available to customers. Mass customisation, however, leverages a combination of online platforms and physical stores, enabling customers to easily configure and order personalised products. These channels are designed to accommodate the individualisation aspect of the business model.

Customer Relationships

In mass production, customer relationships tend to be transactional, with limited engagement beyond the point of purchase. In contrast, mass customisation fosters ongoing and interactive relationships. Customers are actively involved in the product design and configuration process, creating a deeper and more personalised connection with the brand.

Revenue Streams

Mass production generates revenue primarily through high-volume sales of standardised products. Mass customisation, on the other hand, generates revenue from both the sale of customised products and often commands premium pricing for personalised options. This dual revenue stream is a hallmark of the mass customisation business model. Bundling products with customised services could increase the variety of revenue models moving mass-customised business models in the direction of product service systems.

Key Resources

Mass production places a heavy emphasis on efficient production processes and economies of scale as key resources. Mass customisation, in contrast, relies on digital technologies, data analytics, and flexible/reconfigurable manufacturing capabilities. These resources enable the individualisation of products and services. Robustness of the production process is a key success factor for any mass customisation business model.

Key Activities

The key activities in mass production revolve around optimising production efficiency, minimising variation, and ensuring quality control. In mass customisation, the focus shifts to customer engagement, the development of user-friendly product configuration tools, and maintaining

flexible production setups to accommodate unique customer requests. Choice navigation, which is the capability to guide individual customers through the sales process efficiently and effectively, is thus a key activity.

Key Partners

Mass production typically forms stable partnerships with suppliers and distributors to ensure a streamlined supply chain. In contrast, mass customisation extends partnerships to include software developers, data analytics firms, and even customers themselves. These partners contribute to the co-creation process, facilitating the personalisation of products and services.

Cost Structure

Mass production's cost structure is geared towards minimising production costs and achieving economies of scale. In mass customisation, costs may be higher due to the individualisation process but are often offset by premium pricing for personalised options and the operational efficiencies gained through technology-driven processes.

Specific modifications for implementing mass-customisation business models

Building on the generic description of how to move from a standard to a new mass customisation business model for the future of manufacturing, it has been described how to implement it profoundly and successfully, considering reconfigurability, modularity, agility and sustainability.

Reconfigurability and modularity

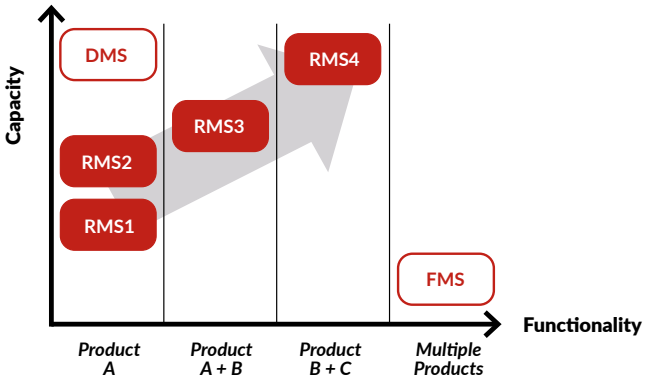
When the concept of mass customisation was popularised in the 90s, the ideas of product and process modularity emerged too. While customisation of physical product offerings can add significant value for both enterprises and customers, complexity and uncertainty often increase as well, i.e. in terms of a higher number of parts, processes, suppliers, distribution channels, demand volatility, delivery lead times, planning effort, setup times, etc. Compared to requirements met by previous manufacturing and business paradigms, mass customisation encompass low cost, high quality, high variety, and rapid responsiveness. Thus, solutions for balancing economies of scale and economies of scope, i.e. reaching customised offerings while keeping complexity, uncertainty and cost to a minimum, has become a key challenge. Product-related mechanisms, such as modularisation of the product architecture and reuse of a product platform across variants in a product family have for a long time been successfully used in a plethora of industries and product segments. A well-known example is the "Modulare Querbaukasten" (MQB) concept by Volkswagen, which ensured high variety, unit cost reduction, and fewer engineered hours per vehicle, through standardisation of design and commonality of parts and subassemblies. However, in itself, modularisation approaches to product development do not ensure effective use of manufacturing or responsiveness. However, in combination with an appropriate reconfigurable and modular manufacturing setup, affordable product variety, efficient customisation, high quality, and rapid responsiveness can be achieved.

Compared to mass production, reconfigurable manufacturing concepts enable both physical and logical responses to changes in product variety and production volume[165]. The concept of the Reconfigurable Manufacturing System (RMS) was initially introduced in the late '90s by Professor Yoram Koren, as an extension of the Flexible Manufacturing System (FMS)[166]. The RMS essentially combines the high volume and efficiency known from traditional dedicated manufacturing lines and the flexibility and adaptability known from the FMS. The key feature of the RMS in regard to supporting mass customisation is the ability to be continuously changed, in order to have the exact functionality and capacity needed to produce a variety of existing product and part families, as well as new products or parts[167] (see Figure 28). This is essential to reduce the traditional trade-off between productivity/efficiency and flexibility, which is a key concern in mass customisation businesses.

Figure 28

RMS meeting both efficiency and flexibility

(Source: Koren, Yoram, et al. "Reconfigurable manufacturing systems." CIRP annals 48.2 (1999): 527-540)



The ability to reconfigure manufacturing systems, equipment and processes is brought about by six core characteristics: customisation, convertibility, scalability, modularity, integrability, and diagnosability[168]:

- Customisation: system and machine flexibility being limited to meet requirements of product and part families

- Convertibility: easy change and transformation of functionality to new requirements
- Scalability: easy modification of capacity
- Modularity and integrability: system and machine functionalities being grouped in smaller units/building blocks with standard interfaces that can be easily combined
- Diagnosability: easy detection and diagnosis of errors during reconfiguration and ramp-up.

Within a mass customisation business model, reconfigurability and modularity can be utilised for reusing equipment and processes across product variants, product families, and product generations. Instead of designing new manufacturing systems for each product/variant, the production system is designed at the outset for reconfiguration in accordance with several product types and generations. Many companies worldwide are utilising these principles to increase competitiveness. For instance, Volvo Trucks in Sweden is implementing modular manufacturing principles to meet a more sustainable future and in order to adapt quickly to new technologies and product models. Moreover, market-leading innovative companies like Vestas Wind Systems and Grundfos use modularity and reconfigurability in the manufacturing setup to increase the utilisation of equipment, increase return on investments, and are adapting the manufacturing setups to changing product models and customer demand[169].

Agility

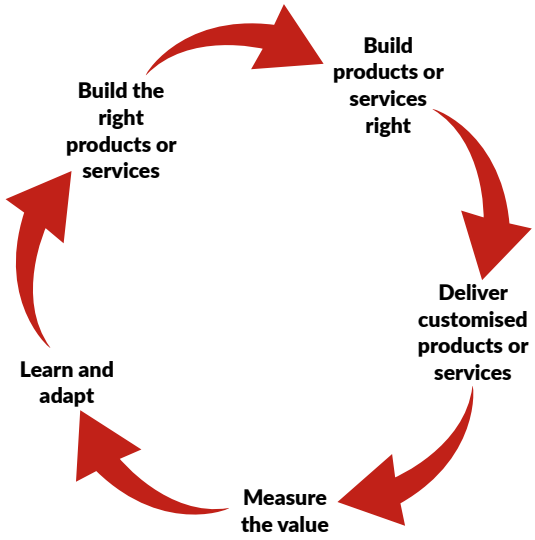
The evolving requirements of customers and the dynamic nature of markets necessitate more than just the mass customisation of products and services, but also proper capabilities to effectively adapt to swift changes. Agile manufacturing surfaced as a competitive concept in the late 1990s to address these business challenges. Although mass customisation and agile manufacturing are interrelated, they have mostly been developed and promoted in close separation. As underlined by recent studies[170 171 172], agility is a must for mass customisation to meet current business challenges. Agility can be seen as the capacity of companies to adapt promptly and efficiently to shifts in market demand, with the objective of satisfying diverse customer needs spanning price, specifications, quality, quantity, and delivery.

Continuous improvement of agility in manufacturing companies is a useful means of overcoming mass customisation limitations with regard to changing customer requirements and business environment. This is consistent with the idea of shifting the improvements from large and long-term projects controlled by few people to more frequent activities involving all company staff[173 174].

In this vein, mass customisation is seen as part of a larger ecosystem for enhancing enterprise maturity in terms of agility and customer-centricity. A central process within such ecosystems involves continuously learning, adapting, creating and measuring value (see Figure 29). Value creation involves building the right products or services, in the right way (i.e. proper solution space definition) and delivering them to customers.

Figure 29

Continuous improvement of mass customisation



This process involves several stakeholders from within and beyond the boundaries of the enterprise, e.g. marketing, design, production, quality, customer, suppliers, etc. Therefore, a shift is needed from a functional silos structure of organisations to cross-functional teams. This can be supported by working on decomposition and modularisation of the processes. Recent trends in consultancy domain mainly in industrial management echo these shifts. For instance, Nakka and Ram[175] promoted the agile ecosystem and how to make it work. Generally, collaboration, team culture and empowerment are key to keeping up with the changing business context. In addition, planning and budgeting should evolve to accommodate changing requirements and scope over time.

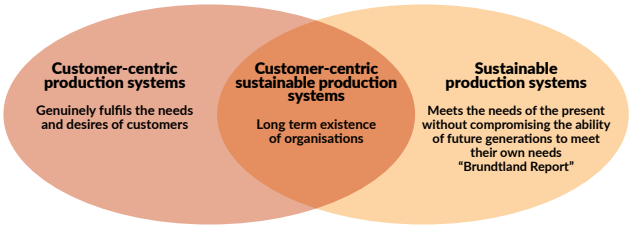
Sustainability

In light of tremendous ecological challenges with Earth beyond six of nine planetary boundaries[176], it is impossible to propose a future business model without considering the respective sustainability implications. The challenge is to find win-win strategies that are beneficial for the company, its customers, as well as society and nature. One of the prerequisites for the success of such strategies is a customer orientation, making it possible to better understand the customer's expectations and integrate them into the strategy. Thus, orientation towards sustainable customer-centred systems is one of the keys

to ensuring the long-term survival of organisations[177] (see Figure 30).

Figure 30

Customer-centricity and sustainability



Based on the assumption that mass customisation cannot be regarded as a sustainable business model per se, it can, however, be seen as an enabler for sustainability in various areas of a business model if designed intentionally. Combining mass customisation with sustainability considerations results in various sustainable business model patterns - 'sustainable solutions space development' - tackels the integration of sustainability into the solution space development, assessing a solution space efficiently (e.g. with lifecycle assessments) and ensuring sustainability thinking on an entire solution space level[178]. "Sustainable configuration" involves combining the customer co-creation with awareness and eco-design, incorporating environmentally and/or socially conscious choices in the user-interface[179]. This involves e.g. informing customers about the sustainability impacts of their choice. For 'reparable and upgradable products', modularity serves as a key enabler for offering a wide variety of products while still benefiting from near mass-production efficiency. If the product design is undertaken from the beginning while also thinking about the whole lifecycle, modularity can facilitate product upgradability and reparability, promoting the adoption of the Circular Economy[180]. Further, mass customisation enables a 'produce-only-what-you-(can)-sell' logic: instead of in-stock production, mass customisation business models are usually based on the principle of build-to-order. Thus, the final manufacturing of the individual product does not start until the customer order is received, avoiding overproduction and the need for storage facilities. Companies that implement a mass customisation business model should not only look at their own operations, but also at the usage phase. The 'sustainable usage' business model pattern reflects the assumption that mass customisation is also suitable for improving the environmental impact during the use phase. To enable sustainable usage, upgrade options and adaptive customisation are crucial. Adding 'additional services' to a mass customisation business model helps in going beyond the system boundaries. Through services (e.g. take-back, offset, transport, updates, warranty), the company is able to improve the whole system in a sustainable way[181].

MASS CUSTOMISATION BUSINESS MODEL CANVAS

Key Partners
- √ Software developers
- √ Data analytics firms
- √ Customer involvement in co-creation
- √ Facilitation of product and service personalisation

Key Activities
- √ Customer engagement
- √ User-friendly product configuration tools
- √ Flexible and robust production
- √ Efficient and effective choice navigation for customers
- √ Complexity management
- √ Lean change management

Key Resources
- √ Digital technologies
- √ Data analytics
- √ Flexible manufacturing capabilities
- √ Robust production processes

Value Propositions
- √ Tailored and personalised solutions
- √ Alignment with specific customer requirements and desires
- √ Unique value proposition
- √ I-designed-it-myself effect in B2C markets

Customer Relationship
- √ Ongoing, interactive relationships
- √ Active customer involvement in product design and configuration
- √ Deeper and more personalised brand connection

Channels
- √ Online platforms
- √ Physical stores
- √ Easy product configuration
- √ Personalised ordering options

Customer Segments
- √ Narrow, highly segmented customer groups
- √ Individual customers
- √ Diverse preferences and needs catered to

Cost Structure
- √ Individualisation process costs

Revenue Streams
- √ Customised product sales
- √ Premium pricing for personalised options
- √ Dual revenue streams
- √ Potential for bundling products with customised services

Servitised Business Models

Product-service systems definition

Product-service systems are the larger mechanisms that deliver both items and services. A product-service system includes a service delivery system (i.e. the manufacturer's operations), as well as any financing systems (i.e. financial leasing) and supplier systems (i.e. consumable supply). Product-service systems provide several 'touchpoints' that contribute to the overall 'customer experience'.

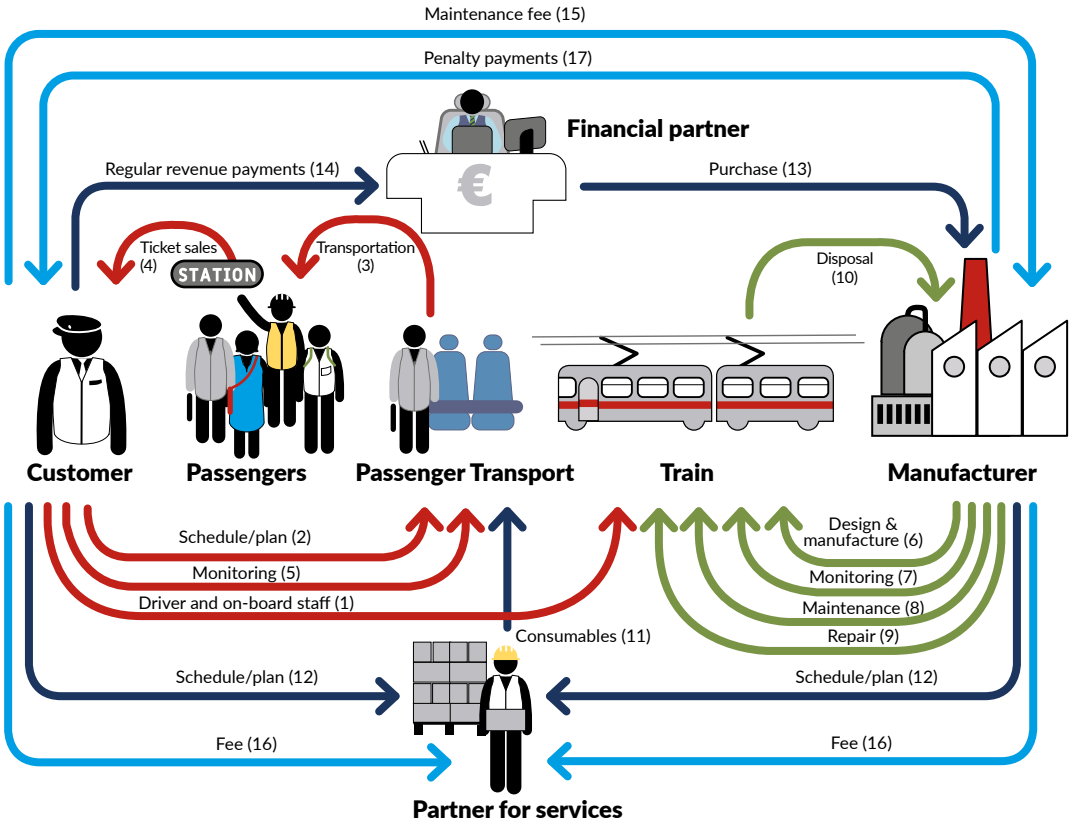
There are few 'touchpoints' in the manufacturing environment since the emphasis is entirely on the product-selling transaction[182]. Longer-term client connections are developed, but they merely result in sales transactions being repeated. These touchpoints are extended beyond the time of sale and throughout the contract's lifecycle by advanced services. They start with contacts between sales representatives, technicians, and project managers and go up to contract formation and implementation. Figure 31 depicts the concept of the Product-service systems in the railway.

As stated in the preceding paragraph, Product-service systems are extremely complex systems with several stakeholders, each with their own approach and aims. There are several conditions that must be met in order to create an effective Product-service system in the firm. The prerequisites can be classified into two categories: technical prerequisites and non-technical prerequisites[183]. Data management, technology management, product and service characteristics, and so on are technical requirements. Non-technical requirements, on the other hand, include management understanding of services, organisational culture and structure, human resource management, and so on[184]. Product-service systems are becoming more popular in both business-to-business (B2B) and business-to-consumer (B2C) industries. As a result, Product-service systems are an excellent method for manufacturers and service providers to improve the sustainability performance and management of their products throughout their lives. The EU Action Plan 2020 has the potential to significantly increase PSS in Europe[185]. Additionally, from a developed countries' perspective,

Figure 31

Product-service systems – railway example

[Source: T. Baines and H. Lightfoot, Made to Serve: How manufacturers can compete through servitization and product–service systems. John Wiley & Sons, Ltd, 2013]



Product-service systems can be an appealing option to move to a service economy in industrialised countries, which consume more resources and create more pollution. Proposed new product and service combinations based on existing, albeit developing, technology realities, necessitate a cultural transformation in order to reframe consumer demands away from product ownership. On the other hand, a business application of Product-service systems may supplement other political and economic interventions in developing countries and serve as an opportunity to facilitate the process of industrialisation by leapfrogging or passing through the stage characterised by individual consumption/ownership of mass-produced goods to the more advanced service-economy[186]. Product-service systems give a more hopeful and ecologically 'lighter' approach of contributing to industrial growth due to enhanced system efficiency.

As a result of the servitisation process characterising the manufacturing context, which puts an emphasis on the benefits generated by shifting from the traditional product sales to service or a combination of products and services sales discussed in the relevant "Servitisation economy" section of Chapter 2, new business models arose and shaped manufacturing companies' portfolios. Commonly referred to as Product-service systems (PSS), they are bundles of products and services designed and integrated with one another in order to fulfil customer needs. These business models are complex systems characterised by four main components: (i) tangible products representing the material and added value of manufacturing delivered to customer; (ii) intangible services, where the value derives from the direct and indirect interactions between customer and service provider; (iii) the system that unites them consisting of all the materials, infrastructure, human resources, and (iv) the network within the system. Considering this complexity there is no unique PSS business model but multiple solutions that depend on customer need.

The Business Model Canvas is a strategic tool that offers companies a systematic framework for defining, visualising, and analysing their business models. When it comes to Product-service systems, the Business Model Canvas acts as an adaptable framework for firms to map out the many components of their PSS strategy[187]. Therefore, following the logic of the Business Model Canvas, general potential modifications to every element of the Canvas due to shift from traditional business models to PSS are detailed in the following sections.

Value Proposition, customers, relationships and channels

The value proposition of enhanced **product value** through added services lies in augmenting the core product with supplementary services, offering convenience, cost savings, and an improved user experience. Tailored solutions and outcomes for customers providing personalised solutions directly align with individual customer needs, boosting efficiency, satisfaction, and market insights. Enhancing 'green' credentials involves adopting eco-friendly practices and materials, which not only reduces environmental impact and operational costs but also appeals to environmentally conscious consumers. This is to satisfy the **customers**, which are mainly: segmented customer groups that value holistic solutions focused on customers seeking outcome-based contracts - they seek service providers willing to align their compensation with the achieved outcomes, ensuring that their investment directly correlates with the desired results. Such customers often include businesses looking to minimise risk, improve efficiency, or achieve specific performance metrics. Digital agencies specialising in service technology development primarily cater to other businesses seeking to enhance their digital presence or streamline their operations. Experts and the green customer segment encompass individuals or organisations with a strong commitment to environmental sustainability. Experts in this context could refer to environmental consultants or sustainability advisors, while green customers are those who actively seek eco-friendly products or services. In the context of PSS in Manufacturing, the primary ecosystems are established among companies, particularly within the B2B market[188]. Additionally, there is a secondary market, B2C, where production companies enhance their products with services and sell them directly to end-users.

In PSS business models the relationship with the customer is fundamental, because the profitability of the services depends on this. Customer relationships built on personal assistance focus on providing individualised support and guidance to customers. The co-creation of value and solutions with customers - in this customer relationship model, businesses actively engage with their customers in the process of creating value and solutions. Continuous service interactions and communication - customer relationships that prioritise continuous service interactions and communication are characterised by ongoing engagement and dialogue. For the abovementioned reasons, the **channels** which allow communication and interaction with customers have special attention in PSS. Indeed, these business models provide several 'touchpoints' that contribute to the overall 'customer experience'. These touchpoints are extended beyond the time of sale and throughout the contract's lifecycle by advanced services. Particularly useful are digital channels which can transform communication, online services, and maintenance from traditional methods to online instruction through platforms such as Zoom and Webex. Additionally, companies can incorporate digital assistants, like chatbots, to address frequently asked questions. Digital channels also streamline collaborations among B2B partners through various collaboration or CRM platforms[189].

Key Resources, processes and partnerships

The Business Model Canvas provides an overview of the key elements necessary to develop a successful PSS. These elements are divided into two main categories: key resources and processes, helping us identify potential partners.

Resources are the assets required for the creation and delivery of value proposition through the various channels described before. The **key resources** that underpin the transition from traditional business models to PSS encompass technology platforms for service delivery (such as IoT and analytics tools), service-oriented personnel and training resources, robust financial and R&D capabilities, logistic centres (e.g. for spare parts), customer feedback and/or product usage data that can enable the design of new services. Along with the resources, it is also essential to develop and carry out appropriate and well-organised **activities** in order to fulfil the value proposition established by addressing consumers' demands. In the case of PSS, it results in fundamental efforts in the design phase of new services and the delivery process of existing ones in order to continuously try to attempt customer requests. Services are means for facing competition, thus monitoring and controlling activities are fundamental for tailoring adequate service offerings. Since services come along with the products and have the purpose of extending and optimising their lifespans, manufacturers should foster continuous product-service integration and innovation. Another important activity relies on the establishment of an ecosystem plan involving all the stakeholders (manufacturers, service providers, customers).

PSS business models extend **partnerships** to include service providers (which can be the manufacturers themselves if they have the resources), IT providers, and even customers themselves.

SERVITISED BUSINESS MODEL CANVAS

Key Partners
- √ Service providers
- √ IT providers
- √ R&D companies
- √ Service ecosystem companies

Key Activities
- √ Service design and delivery
- √ Continuous product-service integration and innovation
- √ Monitoring and control
- √ Establish an ecosystem plan

Key Resources
- √ Service-oriented personnel and training resources
- √ Technology platforms for service delivery (e.g., IoT, analytics tools)
- √ Strong financial and R&D capacity
- √ Logistic centres
- √ Customer feedback and/or product usage data

Value Propositions
- √ Enhanced product value through added services
- √ Tailored solutions and outcomes for customers
- √ Improved "green" credentials

Customer Relationship
- √ Personal assistance
- √ Co-creation of value and solutions with customers
- √ Continuous service interactions and communication

Channels
- √ Sales channels configuration
- √ Service portal or platforms for delivery and communication
- √ Web-based platforms for solutions configuration

Customer Segments
- √ Segmented customer groups that value holistic solutions
- √ Focus on customers seeking outcome-based contracts
- √ Experts and green customers

Cost Structure
- √ Investments in service infrastructure and technology
- √ Ongoing costs for service delivery and relationship management
- √ Direct labour costs

Revenue Streams
- √ Invoicing (directly or indirectly)
- √ Pay-per-use model
- √ Potential for up-selling or cross-selling services

Circular Business Models

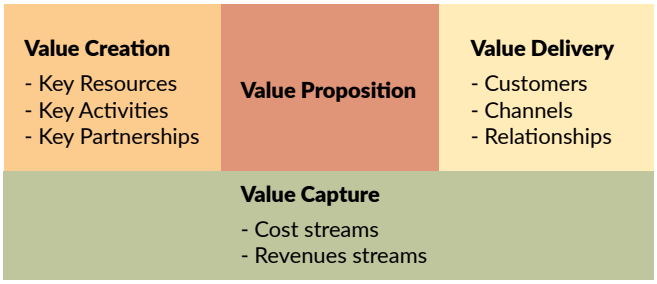
When analysing the economic viability of the Circular Economy (CE), it is important to consider several 'value' aspects through the business model approach. These business model components can identify the different CE strategies which can give rise to not only economic but environmental and social outcomes as well. The circular business model comprises the following aspects:

1. Circular value proposition: what value does the company create, for their customer and for society as a whole?
2. Circular value delivery: how does the company deliver value, i.e. through which customer segments, channels, and relationships?
3. Circular value creation: how does the company create value, i.e. through which resources, activities, and partnerships in the value chain?
4. Circular value capture: what are the main costs and revenue streams?

Accordingly, these elements can be represented in the business model canvas as shown in Figure 32.

Figure 32

Circular business model canvas elements



Circular value proposition

The success of a circular business model is **dependent on the value it creates not only for customers but also the value generated for the environment and society as a whole**. The more effectively a circular value proposition is designed, the more likely a customer will be willing to invest in that product. Circular propositions can be offered as a product (that is designed to enable product-life extension), a product-related service, or a pure service (that may extend to virtual forms as well). Some value examples of propositions (as described earlier in cases where companies are successful in implementing circular business models) are sharing-based (BlaBlaCar), product-service-systems such as pay-per-light (Philips), or customer incentivisation through buy-back or take-back schemes (FairPhone and TeqCycle), etc.

A circular value proposition can benefit all aspects of the sustainability triple bottom line in the long term. From an **environmental** point of view, companies can propose environmental value through resource efficiency, through the reduction of greenhouse gas emissions (e.g. energy recovery from waste and renewable energy use), a reduction in natural resource consumption (e.g. renewable resource use), a reduction in waste generation, resilience to resource scarcity (e.g. a reduction in dependence on finite raw materials) and supply chain disruptions. From an **economic** point of view, value is proposed through the offering of durable and better-quality products for customers, who will spend less, since circular business models provide cost-saving opportunities in the long term, as well as promoting the local economic development of societies, the formation of closed-loop systems through material reutilisation and market differentiation. From a **societal** point of view, a circular offering may propose job creation opportunities, where customers are motivated by environmental considerations demonstrating an increased awareness and preference for eco-friendly options, community engagement and overall social wellbeing; companies that offer comprehensive support throughout the entire product lifecycle, particularly from a service perspective, are in higher demand: customers increasingly buy from organisations that support social causes/charities, increased customer loyalty, trust and brand reputation (manufacturer can meet commitments).

Circular value delivery

Customers

In a circular business model, customers represent one of the most relevant stakeholders in making circles happen. Among all considerations, the final users need to be committed to giving products back once they have no more value for them. For this reason, this business model requires the targeting of a specific niche of the market composed of consumers who have been **environmentally committed** since the very beginning. On the one hand, companies struggle to create the right **awareness and consciousness** in customers to avoid the mishandling of products (e.g. throwing away potentially renewable resources). On the other hand, customers need to be aware of the presence of support systems like a structured reverse logistics network, and in this regard, they need to be educated in using them. Indeed, through the establishment of proper forward logistics and reverse logistics networks,

companies enable consumers to participate in the appropriate returning and regeneration of resources. Circular business models based on PSS mainly address customers who have an **'access over ownership'** mindset (such as young generations, the "Greta effect") and those who occasionally use the product, by optimising the user's cost compared to a high initial investment and a low rate of product utilisation. Circular business models based on reuse and remanufacturing usually target customers who are looking for **cost-saving opportunities**, since reused and remanufactured products are often sold at lower prices than new ones.

Channels

In circular business models, the establishment of channels and thus, the decisions about how to communicate and interact with customers, need to be set by thinking especially about how to engage them in making resources cycle. Both **online and offline** channels are required to keep alive and continue the interaction with customers. Online channels are needed especially to educate, attract, and transfer all the information needed to make them aware of how to properly use and give back the products. Offline channels, like stores, enable the physical collection of exhausted products. To give an example, a cosmetics company has created a strong network of stores as physical channels to sell new products, refill finished products (such as hand cream), and collect the packaging of exhausted products. The online channels are used to show the company's values and mission, to share information about how to reuse products, and where to return exhausted products. In this context, the **local economy** is strongly supported, and **urban factories** are easily established. These new concepts of factories, hence, enhance the engagement of consumers through the **codesigning of products** leading to the creation of circular products which embed the **right-to-repair** principles, which can be accomplished through the delivery of repairing servicing.

Relationships

Unlike traditional business models, circular business models (especially those based on Product-service systems (PSS)/servitisation) try to create a **long-term relationship** with customers thanks to specific agreements and/or services offered (such as warranty, maintenance, repair and technical assistance on products, etc.). Communication, and in particular **storytelling**, is a useful tool for this purpose, as it highlights the environmental and social benefits of circular business models compared to traditional solutions. In this way, circular business models mainly use online channels (e.g. dedicated website pages, blogs, or social media) where companies publish news or articles about them or about the environment. Building long-term relationships with customers is also important, since in circular business models, '**customers become the suppliers'** of end-of-life products that will become secondary raw materials for reuse, remanufacturing, and recycling. Building strong relationships helps in overcoming the uncertainty about returning products in terms of volume, quality, and time.

Circular value creation

This stage comprises the key resources, activities and partnerships needed to create value in a circular economy. It is a dynamic process that requires ongoing innovation, collaboration, and adaptation to evolving technologies and dynamically changing market trends.

Key Resources

Resources are the assets required for the creation and delivery of value proposition through the various channels already described. Circular economy can guide the choice of input materials such that they belong to **closed-loop material** flows or in the form of direct substitution through the regeneration and restoration of natural capital[190]. **Dynamic capabilities** are another key resource that can help develop and refine circular business models, thus generating resilient organisations[191]. Internal capabilities related to marketing, information management, innovation, resource leveraging or networking can provide ample 'sensing' opportunities to understand customers' preferences, behaviour, and demand for circular products and services, which are crucial for designing offerings that resonate with the market.

Another resource in the current pursuit of a smart circular economy is **digitalisation tools** that can help leverage the transition to the circular economy. Technologies such as the Internet of Things and big data analytics can act as important enablers for remanufacturing, recycling and reuse[192]. Blockchain can help transform operations for the implementation of circular economy by improving information transparency and reliability in supply chains. Digital product passports can enable a seamless exchange of product information, especially those related to traceability and circular information, thus reducing the environmental impact of products throughout their lifecycles. Investments in knowledge and skill development of employees (upskilling and reskilling especially in DeepTech, etc.) through training programmes are other vital resources for the creation of value in a circular economy.

Key Activities

To achieve the value proposition set by meeting customers' needs, it is fundamental to establish and implement proper and well-organised activities. In particular, considering the

higher impacts generated through the decisions undertaken at the product's beginning of life, it is of prior importance to define how to **redesign products** to eliminate or reduce detrimental impacts over the entire product lifecycle. Products in this context must be designed **with the intention to be regenerative**. Thus, they need to be easily disassembled to regenerate the resources embedded into products to extract the remaining value through the reuse of the product as it is, the remanufacturing of the product or the recycling of the materials. In circular business models, the **ownership** of products will often remain within the company's boundaries, thus providing customers with all the services needed to support both the product's middle-of-life (e.g. proper usage to extend the product's lifecycle) and end-of-life (e.g. to make possible the materials and components recycling or the product reuse or remanufacturing) lifecycle stages. The recirculation of the resources is relatively easy when **tailored services** are delivered to consumers, among which the possibility to collect products at the end of their lifecycles. Indeed, to make these processes possible, several stakeholders are required to be involved and they need to be linked through a proper infrastructure.

The **establishment of a reverse logistic network** requires defining the roles of all the stakeholders involved and their active participation in both industrial symbiosis networks (external to the traditional supply chain) or closed-loop supply chains (internal to the traditional supply chain). In both cases, structured information flows need to be established to **share information** about the type of resources they either are exchanging or recirculating. Finally, to ensure that all these key activities introduced are providing benefits to the system, **monitoring and control activities** are needed to be established as well. Therefore, monitoring and control can be considered strategic activities too in this context. A set of key performance indicators needs to be framed so that they would be able to provide relevant information to make decisions that impact both, the long- and short-term.

Key Partners

Strengthening relationships and building mutual trust among key partners without whom companies cannot do business, entail a logical next step in circular value creation. These partners can be a part of the linear supply chain, closed-loop value chains or global ecosystem networks. Some examples of key partnerships are **third party reverse logistics providers for take-back schemes** (waste management and recycling companies), partners who can provide secondary/circular materials/products, or who can recover or refurbish products into secondary materials for resale. Partnering with **governments and regulatory bodies** can lead to policy generation and the generation of standards that promote circular incentivisation. **Collaborating with customers** can facilitate engagement and feedback to understand preferences and management of using circular products. Partnering with **funding agencies**, **venture capitalists and investors** can help scale up circular innovations. The strategic alliance of "Green Supplier Selection" has emerged as a pivotal facet in the transition towards a circular economy. This collaborative endeavour underscores the significance of environmentally conscious sourcing practices in the pursuit of sustainable and regenerative economic models. Commercial collaborations seen in the 'industrial symbiosis' model of the circular economy allow the exchange of surplus energy, materials and wastes among companies in close geographical proximity. This approach enables the attainment of environmental goals, including the mitigation of CO2 emissions and resource utilisation, while concurrently conferring a competitive edge through the identification of markets for residual by-products.

Circular value capture

In circular business models, value is captured from the sales of reused and/or remanufacturing products which usually have a **lower price due to reused components and secondary raw materials**, which are often cheaper than new virgin ones, especially if their availability is scarce. In some cases, value is also captured from the offering of additional services (maintenance, leasing contracts). In circular business models based on PSS, revenues mainly come from the **periodic fee** paid by customers, usually coupled with an initial deposit. Since circular business model activities such as repair and remanufacturing are usually more labour- intensive than traditional manufacturing ones, circular business models often have higher labour costs than traditional ones. Indeed, most of the repairing and overhauling activities can be carried out only manually. Disassembling, checking the components, replacing parts, and reassembling products are rarely automated, and need skilled technicians. In addition, a circular business model based on PSS must bear the initial product cost, which represents an anticipated and risky investment (time mismatch between revenues and costs, leading to cash flow issues -leading to cash flow issues, i.e. short-term costs vs long-term revenues.

Other important costs are **maintenance and service lifecycle costs,** as well as **reverse logistics**, which does not include only the transportation cost, but also inventory, spare parts, etc.

Future opportunities

Circular economy promotes a net-positive approach to achieving sustainability goals by helping companies create more handprints than the more retrospective footprint calculations[193]. The circular business model canvas could be one way in which manufacturing companies could track this progress towards a net-zero future.

CIRCULAR BUSINESS MODEL CANVAS

Key Partners

- √ Third-party reverse logistics providers for take-back schemes
- √ Governments and regulatory bodies
- √ Customers become suppliers
- √ Funding agencies, venture capitalists and investors

Key Activities

- √ Circular product redesign
- √ Service management and tailored services
- √ Reverse logistics planning and control
- √ Tracking and monitoring

Key Resources

- √ Secondary materials from closed-loops
- √ Dynamic capabilities
- √ Digital tools

Value Propositions

- √ Environmental value (resource efficiency, resilience to resource scarsity)
- √ Social value (increased customer loyalty, community engagement)
- √ Economic opportunities (longevity and better-quality products leads to cost reduction, market differentiation)

Customer Relationship

- √ From one-time to long-time relationships
- √ Storytelling to engage and raise environmental and social awareness

Channels

- √ Customer engagement in take-back systems
- √ Online and offline engagement channels

Customer Segments

- √ Environmentally committed, aware and conscious customers
- √ Access over ownerships mentality
- √ Young generations (Greta effect)

Cost Structure

- √ Labour costs (labour-intensive activities such as remanufacturing)
- √ Financial costs (higher time mismatch between high initial investments and revenues split over time)
- √ Maintenance and service lifecycle costs
- √ Reverse logistics costs

Revenue Streams

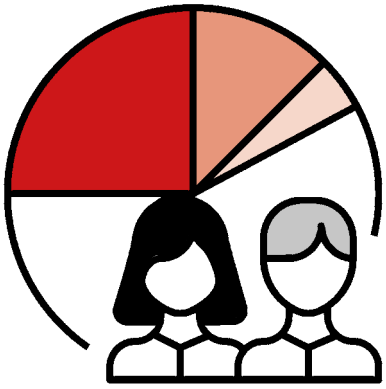
- √ Cost savings (secondary raw materials)
- √ Stable cash flows over time (leasing, pay-per-x, etc.)

4

Key Recommendations

The World Manufacturing Foundation, in collaboration with global experts, is pleased to present the Ten Key Recommendations of the 2023 World Manufacturing Report. We hope that our readers can take inspiration from these recommendations and work together to embrace new business models while maintaining their strong competitive advantage.

1. EMBRACE A CUSTOMER-CENTRIC INNOVATION APPROACH TO FOSTER LOYALTY AND DRIVE GROWTH



- **Skills:** **Train the workforce in design thinking, user experience (UX), and customer relationship management (CRM).**
- **Technology:** **Embrace technologies that enable deeper insights into customer behaviours and preferences.**
- **Policy:** **Adopt transparent data policies and robust cybersecurity measures to safeguard customer privacy.**

In the highly competitive manufacturing landscape, a paradigm shift towards a customer-centric innovation approach is essential for success. More than just keeping the customer in mind, customer-centric innovation is a systematic effort to make the customer the focal point of all strategic and operational decisions. The fundamental premise is that every aspect of the manufacturing process, from product design to service delivery, should be guided by the customer's needs and preferences.

Traditionally, manufacturers prioritise efficiency, cost reduction, and technological upgrades. While these factors are essential, they can overshadow the importance of customer feedback and engagement in the innovation process. In today's digitised and interconnected world, customers are well-informed and have higher expectations of personalisation, quality, and service. Manufacturers who adopt a customer-centric innovation approach can ensure their offerings resonate with their customers, leading to increased loyalty, market share, and sustainable growth.

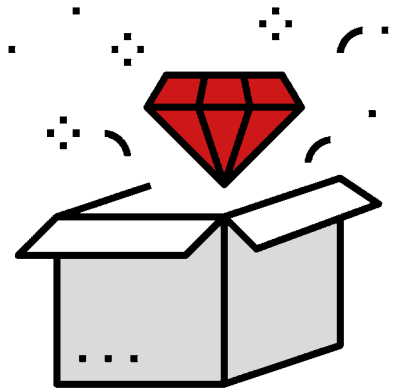
Manufacturers should leverage data analytics and AI to gain granular insights into customer behaviour and preferences, enabling more personalised and responsive product development. A feedback loop where customer feedback directly influences product design and service delivery is essential. In parallel, they should enhance transparency and customer engagement through digital channels, creating a platform for continuous dialogue with their customers.

A customer-centric innovation approach offers numerous benefits. First, it helps ensure that products and services align with current and future customer needs, increasing the success rate of new offerings and reducing the risk of market failures. Customers are more likely to be loyal to companies that meet their needs and value their feedback. This strategy can also streamline R&D by focusing resources on projects with the highest potential for customer impact. Ultimately, a customer-centric approach can strengthen a company's brand and reputation, making it a key differentiator in the market.

Despite its many benefits, a customer-centric innovation transformation is not without risks. Increased reliance on customer data increases the potential for privacy violations and data breaches. To mitigate this risk, companies must implement robust cybersecurity measures and adopt transparent data policies. The shift to a customer-centric culture may also encounter internal resistance, as it often requires significant changes to workflows and mindsets. To overcome this challenge, companies must foster an inclusive culture where employee input is valued in the change process, and clear communication is prioritised to elucidate the benefits of the shift for both the company and its customers.

Moreover, there is a risk of myopia where manufacturers become so focused on current customer feedback that they neglect emerging trends and disruptive innovations. This can be countered by maintaining a dual focus on immediate customer feedback and long-term market and technological trends. This balance ensures that the manufacturer is responsive to current market demands while still capable of driving innovation in anticipation of future shifts.

2. CREATE SUSTAINABLE VALUE PROPOSITIONS BASED ON THE TRIPLE BOTTOM LINE FOR A COMPETITIVE EDGE



- **Skills:** **Equip teams with tools and knowledge about sustainability thinking to better design value propositions.**
- **Technology:** **Reflect on the usefulness and applicability of digital solutions as means for more sustainable products and services.**
- **Policy:** **Create supporting organisms that guide organisations as they intend to embed sustainability in their offerings portfolio.**

By now it is clear that sustainability must become a core part of every company's value proposition and core activities. For a long time, sustainability was at the lighter end of academic discussions, but increasingly this concept is perceived as an utter priority for industrial prevalence. There is no longer any room for sustainability as an afterthought, and the activities that have characterised "business as usual" must change immediately to decouple them from reflecting a linear economy.

Companies need to ensure competitiveness and customer loyalty and be proactive towards mitigating environmental degradation. To achieve all these outcomes and head towards success in an ever-competitive era, companies need to actively question their current value propositions and ensure that sustainability is embedded at the core.

The steps to achieve sustainable results can vary according to the context, but it is suggested that companies balance the needs and expectations of all their stakeholders. Referring to needs and expectations can be challenging. Often customers require some degree of awareness in connection to sustainability transitions, but highlighting the benefits they could experience across short, medium, and long timeframes, can engage them in value co-creation activities.

Further, companies can expect that iteration will be a required principle. Shifting a company's value proposition to embed sustainability might not be an easy task to complete at the first attempt. In this sense, iteration will act as a sound process that develops a company's ability to acquire, combine, and use resources to create and deliver a sustainable value proposition to its customers and capture value for the company.

Also, companies need to engage in increased innovation and transparency. As companies transition and evolve, they are required to embrace as many strategies as possible from the circular economy and identify potential value creation.

Some of the proposals for successful transitions involve companies examining the value that they are missing to capture in their current value propositions under the lenses of: what is the value that we are missing? Is there any value that is being destroyed before we capture it? How are we relating to our customers – is there any surplus? Or absence? Asking the right questions will guide companies and support them to ensure that sustainable value is created.

A notable remark is that for value to be sustainable, it cannot be limited to being only greener and reducing emissions. Sustainable value needs to be defined as one that embeds benefits across the triple bottom line of sustainability from the perspectives of the environmental, social, and economic pillars.

In conclusion, creating sustainable value propositions can benefit from listening to stakeholders' needs, and engaging in iterative processes to redefine value. These actions should be taken in such a way that they engage members of the value chain, such as customers and suppliers, and develop in terms of innovation and transparency by using tools that allow brainstorming and the mapping of future steps.

3. AIM FOR MASS-CUSTOMISED AND PERSONALISED VALUE PROPOSITIONS TO CREATE HIGHER BENEFITS FOR CUSTOMERS

- **Skills:** **Equip teams with training on consumer behaviour and trend analysis to anticipate and cater to evolving preferences.**
- **Technology:** **Implement systems that facilitate customisation at scale, from modular design to advanced manufacturing techniques.**
- **Policy:** **Foster a regulatory environment that encourages innovation while maintaining standards and meeting consumer protection norms.**

The conventional 'one-size-fits-all' manufacturing approach is becoming less and less relevant in today's globalised world. The sophisticated, discerning modern consumer demands customisation in products that meet their requirements. Therefore, embracing mass-customised and personalised value propositions is not just a nice-to-have but a quintessential business imperative. It is a powerful tool to carve a distinctive niche in crowded marketplaces and secure consumer loyalty.

To actualise this, the skillset of the teams involved plays a pivotal role. From design to production, professionals equipped with a nuanced understanding of consumer behaviour can be the difference between a product that resonates and one that does not. Continuous training on trend analysis, market segmentation, and consumer research is paramount. Organisations should prioritise creating a culture where feedback is solicited, valued, and acted upon, with teams agile enough to pivot based on insights garnered.

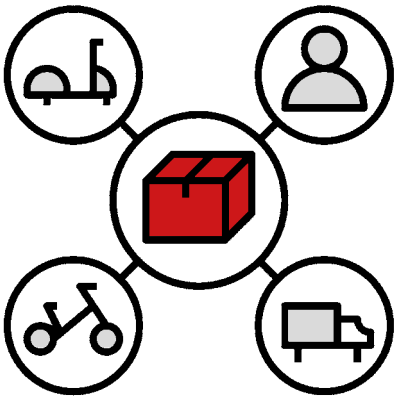
From a technological standpoint, the key challenge is balancing customisation with efficiency. With advancements like modular design, 3D printing, and AI-driven consumer insights, manufacturers can now personalise at an unprecedented scale. It is crucial to adopt and integrate these technologies seamlessly into the production processes, ensuring that personalisation does not compromise time-to-market or inflate costs disproportionately. The agility of these systems will determine how quickly manufacturers can respond to evolving market needs.

On the policy front, while innovation must be encouraged, it is equally important to ensure that products meet established standards and safeguard consumer interests. Regulatory bodies need to strike this balance, fostering an environment where innovation thrives without compromising on safety or quality. This involves continuous dialogue with industry stakeholders, understanding the challenges of mass customisation, and framing guidelines that are both robust and flexible.

Moreover, manufacturers, stakeholders, policymakers, and even consumers share a collective responsibility in shaping the future of manufacturing. While manufacturers focus on delivering personalised products, stakeholders need to support initiatives that drive this innovation. Policymakers should frame regulations that are conducive to this shift, and consumers can play a pivotal role by voicing their preferences and ensuring they support businesses that prioritise their needs.

In conclusion, as we stride into a future where individuality is celebrated, the manufacturing sector must rise to the occasion, delivering products that resonate on a personal level. This is not just about profitability; it is about building lasting relationships with consumers, where products are not just commodities but extensions of their personalities and lifestyles. The success of this endeavour hinges on a harmonised effort from all involved, converging skills, technology, and policy towards a singular goal of unparalleled consumer satisfaction.

4. DEVELOP NEW SALES CHANNELS FOR HYBRID REVENUE STREAMS



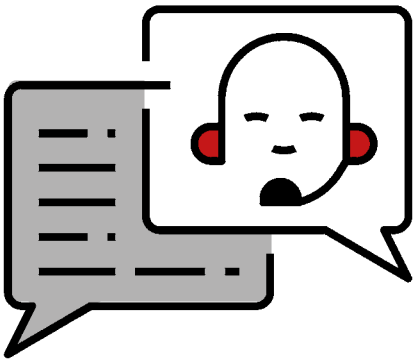
- **Skills:** **Manufacturing companies must utilise a variety of skills, including communication, technical proficiency, adaptability, adoption of sales technology, and networking, to reach the global market through hybrid sales channels.**
- **Technology:** **To serve customers where they prefer to buy, hybrid sales channels combine various channels, such as e-commerce platforms, call centres managed by salespeople, and in-person stores.**
- **Policy:** **Customers should be given the confidence to use digital or hybrid sales channels by determining the appropriate permission and access levels, taking into account specific data privacy concerns.**

Sales channels assist manufacturing companies in presenting their products or services to potential clients. Manufacturing companies may improve process efficiency by streamlining the marketing and sales of their goods and services by establishing the right business channels. When it comes to manufacturing companies' sales channels, business-to-customer (B2C), business-to-business (B2B), and business-to-government (B2G) are the three primary market orientations. Additionally, the B2B market often comprises the primary profit partners. Today's B2B clients have certain requirements that they want to be met by their suppliers, such as more channels for contact, increased convenience, and a customised experience. Throughout their purchasing process, they look for a well-rounded combination of in-person interactions, distant phone or video conversations, and self-service alternatives via e-commerce. B2B firms must switch from inside sales and old tactics to a more flexible "hybrid" approach that accommodates customer preferences to adapt to this shifting market.

According to data from earlier studies, 90% of businesses that changed their sales channels during the COVID-19 pandemic kept the structural adjustments they had made to their sales teams to support a hybrid strategy. Clients are looking for this kind of service, while vendors are looking for more flexibility in their working conditions. Even while the shift to a more digitally-enabled and hybrid sales model was already taking place before the pandemic, prior studies suggest that by 2024, hybrid sales methods should be the norm. The effectiveness of hybrid selling structures is contingent upon the degree to which sales managers incentivise, recognise, and equip their sales teams to function efficiently in the contemporary landscape, which necessitates a substantial shift in ingrained beliefs and sales methodologies. For effective client attention, hybrid sales channels demand strong cross-functional integration between channel partners as well as between buying and selling organisations. Additionally, within field sales teams, research identifies team-level variables like team spirit, goal congruence, quality of the interpersonal climate, consensus, etc. as important factors in the interaction and coordination that lead to successful sales team performance. The synergies that arise from working together reduce the likelihood of goal incongruity and conflict. The efficiency of hybrid sales models in creating client value may also be influenced by shared team experience.

To be more competitive in the global market, manufacturing companies are advised to implement hybrid digital sales channels. Manufacturing companies that want to succeed with hybrid digital sales models must do the following: (1) create online and remote channels without completely abandoning in-person sales; (2) fully understand the needs of the customer throughout the sales process; (3) implement appropriate digital technologies to enable hybrid sales channels; (4) anticipate the future purchasing habits of the new generation of customers to create appropriate sales models for the future. In comparison to more traditional models, manufacturing companies that appropriately employ hybrid sales channels can generate up to 50% more revenue by facilitating deeper, broader customer engagement and opening up a more diverse market.

5. FOSTER TIGHTER BONDS BY CREATING IMPROVED CUSTOMER RELATIONSHIPS



- **Skills:** **Develop soft skills, such as openness, communication, and trust.**
- **Technology:** **Make use of digital technologies such as sensors to achieve lifecycle visibility and traceability that can help identify new offerings.**
- **Policy:** **Create frameworks and incentives that promote collaboration to create a space for improved customer-centric business models.**

The shift towards new business models in manufacturing brings with it many implications. Some of them are connected to the advantages identified as part of the shift to business strategies that leave behind a product-centred and transaction-based approach, to welcome increased collaboration, communication, and extended relationships across value chains. In this sense, the relationships a company establishes with its customers present many potential improvements in new business models. For instance, shifting from a transaction approach to business models that focus on the delivery of results or solutions creates a shift where the strategy of companies becomes increasingly relationship-centric. To take advantage of this, companies need to focus on creating awareness and educate themselves and their customers to be able to identify the customers' needs as part of the core of value creation.

The aforementioned shift towards relationship-centric relationships can benefit from leveraging the human aspect that is often overlooked in traditional sales models, thus approaching customers with openness towards increased customisation, actively listening to their needs and engaging in constructive conversations about how this can improve the existing offerings provided; this is part of the future of business models in manufacturing.

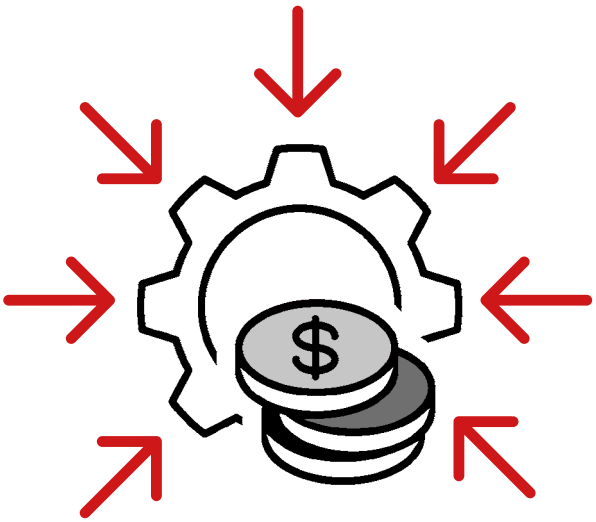
Additionally, companies are advised to pay close attention to the customer experience, making sure that they receive the support customers expect and need to maximise value capture during and after commercial offerings.

Evolving in this manner can support firms in developing the trust needed, both from an organisational perspective, and in relation to the product, service, or bundle offered.

Finally, developing closer customer relationships opens the door for a new era of traceability, where a lifecycle perspective can be taken to follow up on the post-sale functioning of products and services. These activities do not only provide value for the customer but also to the manufacturer, which can make use of data generated through these activities to identify new potential offers.

To conclude, for the successful adoption of new business models, firms need to evolve in terms of how they perceive and involve their customers in the planning of their business offerings, to ensure that they connect through similar values, engage traceability along the lifecycle, and create a space for value co-creation.

6. UNLOCK VALUE POTENTIAL BY HARNESSING AI AND DATA ANALYTICS FOR NEW REVENUE STREAMS



- **Skills:** **Increase focus on the development of AI and data analytics in each team to promote data monetisation.**
- **Technology:** **Evaluate the trustworthiness of data exchange processes and proactively address data-sharing concerns.**
- **Policy:** **Develop regulations that support new revenue distributions and create standards that allow successful collaboration in the shape of data-driven business models.**

Engaging in a business model innovation transition requires companies to successfully create viable business cases. Achieving this means understanding the logic behind sustainable revenue streams.

In today's digitalised era, it is a known fact that there is more data available than ever before. However, creating value from data is a step where many firms are still developing the right skills to frame sustainable value propositions.

Shifting to new forms of business models that decouple value capture from tangible products, and instead prioritise services, results, or outcomes, requires companies to have a clear definition of what is the value the customer expects and how are they willing to pay for it.

In the evolution of manufacturing to embrace new business models, it is expected that there will be changes in traditional customer segments, where the number and type of revenue streams can vary for different businesses. In addition to the definition of revenue streams, companies must consider and analyse potential pricing mechanisms that are best suited to each revenue stream. The monetisation of data engages in a process where companies are witnessing economic benefits. For current manufacturing companies, data is possibly the most valuable asset for driving business transformation. Transforming data into valuable insights allows the capture of tangible value through data monetisation. Most firms can benefit from differentiating their data monetisation strategies according to whether they want to commercialise the data itself, or the insights generated.

In recent years, many companies have created software that can provide prescriptive insights on manufacturing processes, such as companies that commercialise machine tools, and automotive products, among many others.

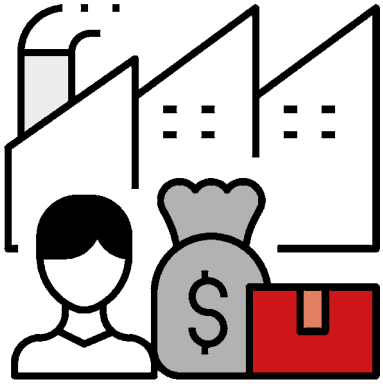
Regardless, one thing is certain – it's necessary to identify revenue streams at early development stages, as there is a larger potential to capture value in the design stage of the business model.

To do so, firms should engage in value co-creation activities with their customers, to identify the actual value of the data generated for customers and other stakeholders. Also, companies need to identify sustainable strategies to manage data. In the process of identifying data management strategies, companies will notice that they need to develop digital trust and plan accordingly for compliance on data-sharing concerns, including GDPR.

A natural consequence is that companies can benefit from embedding ethical practices in the processes leading to data monetisation. But doing so also requires investing in the development of skills connected to data analytics and AI. This way, having skilled employees in organisations who can support the development of new services allows for more robust business propositions. Further, to achieve successful outcomes, companies are required to ensure the engagement of relevant stakeholders both at internal and external levels. Being aware of the initiatives and technologies used across the whole product/service portfolio can help mitigate data silos and isolated initiatives.

Following these recommendations can contribute to the successful monetisation of data and maximise value capture across different revenue streams.

7. BALANCE KEY RESOURCES TO AVOID THEIR OVER- AND UNDERESTIMATION FOR SUSTAINABLE OPERATIONS

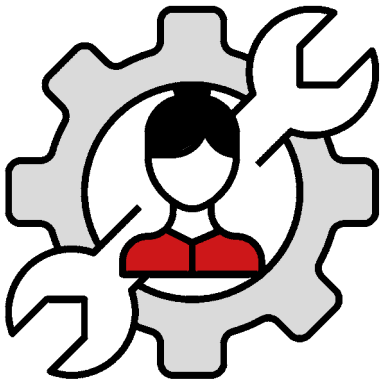


- **Skills:** **Analytical skills and adaptability are crucial for anticipating and navigating resource challenges, while strategic planning and cross-functional collaboration ensure a well-rounded approach to resource management in a dynamic market.**
- **Technology:** **Robust data management and predictive analytics tools enable informed decision-making, while agile technologies and advanced supply chain systems support the adaptability needed for effective resource allocation.**
- **Policy:** **Continuous monitoring and risk management policies facilitate proactive adjustments to resource utilisation, and a focus on ethical data use, innovation, and flexibility in policies ensures responsible and adaptive practices.**

When we take an overview of the business models, especially servitised business models, the key element to making such progress has been making the businesses more competitive and achieving maximum output with personalisation or mass customisation. However, these elemental changes are reliant on the resources at hand. The key resources should align with the requirements of delivering such tailored solutions. So, considering which type of business model we are dealing with, acquiring the right resources to align with the business strategy is important. Secondly, correctly utilising these resources. Thirdly, maintaining the key resources to ensure the continuity of the operationalising of the business model is imperative. However, the estimation of these key resources is the biggest challenge. We have observed that many factors influence the acquiring of the right resources; for instance, the size of the company could be very small. Maybe the company does not have the financial capacity, especially in the case of SMEs. The servitised businesses in the case of SMEs especially have to be careful about not overestimating key resources, as the SMEs typically thrive on their agility and ability to respond quickly to market changes. Overestimating resources, can make the business less flexible, hindering its capacity to adapt swiftly to evolving customer demands and competitive landscapes. Managers in larger companies can easily make the same mistake and cause the misallocation of key resources, thus diverting resources away from areas critical for the success of the servitised business model. Similarly, the underestimation of key resources may limit the ability to gather and analyse customer data effectively. This can result in a generic or suboptimal level of personalisation, diminishing the perceived value of the offerings to customers. Therefore, the collaboration between different departments (e.g. marketing, sales, operations) ensures a holistic approach to resource management; especially now in terms of data analytics, we can anticipate and navigate resource challenges more effectively. Robust data management and predictive analytics tools enable companies to make informed decisions, while agile technologies and advanced supply chain systems support the adaptability needed for effective resource allocation. While talking about adjusting the policy with this background of resource estimation, companies need to make sure that there is continuous monitoring, and risk management policies facilitate proactive adjustments to resource utilisation, and a focus on ethical data use, innovation, and flexibility in policies ensures responsible and adaptive practices.

In conclusion, balancing key resources can be done through regular assessments and adjustments to resource allocations based on data from performance feedback and market dynamics to help businesses optimise their operations.

8. PRIORITISE LOCALISED MANUFACTURING AND STRENGTHEN CORE COMPETENCIES FOR MARKET AGILITY AND SUSTAINABILITY



- **Skills:** **Foster expertise in local market dynamics, supply chain management, and niche production techniques.**
- **Technology:** **Invest in advanced manufacturing systems that allow for agile production and localisation adjustments based on demand.**
- **Policy:** **Advocate for incentives and frameworks that promote domestic manufacturing and sourcing while maintaining global competitiveness.**

The manufacturing landscape has undergone a significant transformation, with the realisation that global, centralised models, while effective in some scenarios, might not always be the best approach. Localised manufacturing, characterised by producing goods closer to where they are consumed, offers myriad advantages from reduced lead times to increased flexibility in catering to local tastes. Alongside this, an unwavering focus on strengthening core competencies ensures that manufacturers can offer unmatched quality and innovation in their offerings.

To begin with, the skills requisite for this shift towards localised manufacturing are multifaceted. Understanding the intricacies of local market dynamics becomes paramount. This includes the preferences, buying behaviours, and cultural nuances of local consumers. Simultaneously, expertise in localised supply chain management ensures that production can be agile, responsive, and cost-effective. It is not merely about producing locally, but producing smartly, leveraging niche production techniques that offer competitive advantages.

On the technological front, the key is agility. Advanced manufacturing systems, which can quickly adapt to changing demand patterns, are the need of the hour. While sophisticated automation systems can guarantee that production lines can be swiftly adjusted to meet local needs, technologies such as real-time data analytics can offer insights into local consumption patterns. Furthermore, the integration of technologies such as the Internet of Things (IoT) can enhance operational efficiency and guarantee the responsiveness of manufacturing units. Policies play a foundational role in facilitating or hindering localised manufacturing. Governments and regulatory bodies must be attuned to the benefits of domestic manufacturing – from job creation to boosting local economies. Policies that incentivise local production, perhaps through tax breaks or subsidies, can act as catalysts. Furthermore, frameworks that promote local sourcing can further strengthen the domestic supply chain. However, it is essential that while promoting localised manufacturing, policies do not inadvertently stifle global competitiveness. A harmonious balance is key.

Manufacturers, stakeholders, and policymakers must collaboratively envision a future where manufacturing is not just about mass production but about meaningful production. This means creating products that resonate with local audiences, produced sustainably using local resources, but without compromising on global quality standards. The role of consumers is also pivotal. By choosing locally produced goods, they can drive this shift, ensuring a future where production is not just efficient but also empathetic.

In wrapping up, localised manufacturing, complemented by robust core competencies, offers a roadmap for the future of manufacturing. It is a future characterised by agility, resonance with local audiences, and a commitment to excellence, ensuring that manufacturers are not just producers but integral contributors to local ecosystems and global innovation narratives.

9. EXPAND PARTNERSHIPS BEYOND TODAY'S VALUE CHAINS' TRADITIONAL BOUNDARIES TO PREPARE FOR NEW CHALLENGES AND RISKS

- **Skills:** **Manufacturers must prepare their workforce to be creative and mindful in their approach to establishing new partnerships and identifying future key partners.**
- **Technology:** **Existing partnerships across the value chain will intensify and integration of digital technologies will deepen, even in core processes.**
- **Policy:** **New, previously unexpected partners will enter the ecosystem and evolve into key partners driven by the need for innovative, new business models highlighting the need for effective policy guiding and simplifying the process.**

Manufacturing has always been a highly collaborative industry. Rarely is a successful manufacturing company not deeply integrated into a network of suppliers, partners, and service providers.

With the dawn of new, innovative manufacturing business models, this integration of collaborators is expected to not only deepen (with existing partners) but widen, by including a variety of new partners that were not previously stakeholders in traditional business models.

Regarding the deeper integration of existing key partners, all functions of the value chain will be affected. From design and engineering to distribution to after-market services and end of life, exchange of data, new ways of profit sharing, and financing of value proposition are necessary. When it comes to the widening of collaborative networks and the addition of new key partners, companies must think outside the box and traditional approaches.

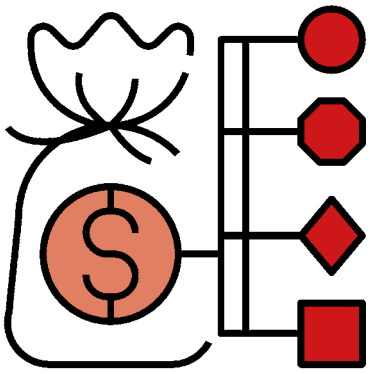
For example, with a highly servitised, non-ownership business model the manufacturer absorbs significant risk, both technically and financially. Adding a key partner with risk management expertise, such as an insurance company that does not simply provide a policy as they did in the past but becomes an integrated partner that works closely with the manufacturer to provide a sustainable solution to the customer, is key.

These new realities associated with innovative manufacturing business models require new and evolved skills outside of the technical arena, e.g. a truly interdisciplinary mindset and the ability to function effectively in diverse teams. Preparing the workforce to interact in an environment outside of their (traditional) comfort zone requires new approaches to training and skills development.

Digital technologies are essential for integrating existing partners more deeply as well as adding new key partners from a variety of backgrounds to the value chain. The effective exchange and analysis of data across value chains will be both a challenge and an opportunity.

New policy is needed to facilitate the new partnerships and help regulate and protect the massive exchange of data across borders. Overall, it is expected that complexity will increase, which further emphasises the need for effective and targeted policy guiding the integration process and, ideally, simplifying the negotiations between new partners with a strong and transparent legal process.

10. OVERCOME INVESTMENT BARRIERS TO ESTABLISH TRUSTING RELATIONSHIPS TO UNLEASH CONTINUOUS CASH FLOW FROM ASSETS



- **Skills:** **Upskilling plays a major role in the success of manufacturers as sales become more technical in nature compared to traditional models.**
- **Technology:** **Sustainable financial planning will be more complex compared to the traditional sales-based business models and will be data-driven and technology-supported.**
- **Policy:** **New, innovative manufacturing business models impact cost structure and require new financial instruments and policy.**

New, innovative business models are expected to have a significant impact on the cost structure and finances of manufacturing companies and value chains. Traditionally, the cost structure of manufacturing operations could be separated (comparably) clearly into fixed costs and variable costs, and the most expensive and essential activities were clearly visible. Most traditional manufacturing cost structures reflect this reality.

With the dawn of new, innovative manufacturing business models that differ to a varying extent from the traditional, sales-based business model, do not necessarily allow for a clear-cut accounting of fixed vs variable costs, and the key expensive and essential resources are not as clearly visible as they were in the past. The more collaborative and integrated approach with many stakeholders further complicates defining transparent cost structures. At the same time, these new, innovative business models require transparent cost structures to function sustainably in a competitive marketplace. These are issues that arise with servitised, non-ownership business models that resemble subscription services.

In such cases, the manufacturer (and its key partners) is responsible for the financing of the products, e.g. a complex machine tool, and will only be able to break even over time with the continuous use of said machine tool by the customer. In the past, at the point of sale, the manufacturer was able to recoup its costs. Not only is there a larger component of financing the operation involved, but also an additional component of more intense after-market involvement, especially in business models where the asset is managed and operated by the manufacturer for the customer for a fee. In this case, to keep operations sustainable requires different planning and cost allocation than in the past. Even the allocation of acceptable costs might be viewed differently, given that the cost structure of after-market services is now absorbed by the manufacturer. Hence, producing more reliable parts might pay off with reduced maintenance costs in the future.

This transition requires a new perspective on the traditional skills model and careful upskilling of the personnel involved. Given the fragility and impact of key financial decisions, this is an essential area that can make or break companies engaging in new manufacturing business models. Controllers most certainly need to expand their perspective and comprehend the complexity and carefully weigh the impact of decisions regarding the cost structure taken.

On the technology side, planning tools that are data-driven and include a large variety of indicators are essential to predict changes in the market and cost structure. The ability to foresee changes is crucial to not falling prey to amassing significant financial liabilities without the ability to recoup the cost over the predicted period of time.

The policy must pave the way to enable manufacturers and their partners to effectively navigate longer-term commitments and an environment providing the financial instruments enabling the new business models' requirements. Policy must address proactively questions around taxation, international collaboration, and liability, and risk, and carefully examine existing frameworks and current policies for potential issues.

Conclusion

The last few years have been characterised by several disruptive events, reinforced by an enhanced awareness of moving towards more sustainable systems relying on the resources available, mainly people and technologies. In this continuously changing environment, one of the main actors is the manufacturing sector, which, with its companies, has to be resilient along a never-ending path of innovation. In detail, as reported throughout the *World Manufacturing Report*, new business models are needed to face new economic needs and trends.

The experts in the field have recognised the supremacy of six main different business models:

- Digital Business Models, according to which the value proposition is orchestrated and supported by digital tools;
- Data-Driven Business Models, according to which the value proposition is derived from the knowledge generated through data gathered on the entire ecosystem;
- AI-based Business Models, according to which predictions and risk management represent the core elements to create value while addressing customers' needs.
- Mass Customisation Business Models, according to which customer needs are broadly satisfied taking advantage of economies of scales;
- Servitised Business Models, according to which the product is recognised as the means by which deliver services and address key customer needs;
- Circular Economy Business Models, according to which the value proposition is supported by the optimised and extended usage of resources.

The six business models, integrated and combined, have led to the delineation of 10 Key Recommendations suggesting urgent actions to address, in the near future, thus covering all the nine building blocks of business models to improve the performance of manufacturing companies.

YML

Young Manufacturing Leaders

Winning Case Studies on New Business Models for the Manufacturing of the Future

YML Contest for the 2023 World Manufacturing Report

Young Manufacturing Leaders is a global initiative for students, young workers and professionals interested in a career in the manufacturing sector. The YML network is strongly committed to raising awareness of the opportunities in manufacturing, and to spreading knowledge of the skills needed in this sector. It supports members with different activities such as peer-to-peer seminars, mentorships with professionals and entrepreneurs, and participation in the activities of the World Manufacturing Foundation.

From July to October 2023, the YML Contest for the 2023 World Manufacturing Report was held, inviting young leaders from all over the world to submit a case study relevant to the topic of New Business Models for the Manufacturing of the Future.

The submissions were evaluated by the World Manufacturing Foundation and the winning case studies are included in this section.

The Young Manufacturing Leaders network initiative, launched in 2020, now has nine partners: Politecnico di Milano, Chalmers University of Technology, Czech Technical University in Prague, the Federation of Estonian Engineering Industry, IMH Campus, Laboratory for Manufacturing Systems & Automation, University College Dublin, University of Porto, and the World Manufacturing Foundation.

The initiative is co-funded by the European Union, within the framework of the EIT Manufacturing programme.

For more information, visit youngmanufacturingleaders.org

YML

Enhancing Sustainability and Resilience through Business Model Innovation for Electrical Engineering SMEs

Patrick Bründl
Research Associate & PhD Candidate, Institute for Factory Automation and Production Systems (FAPS), Friedrich-Alexander-Universität Erlangen-Nürnberg - YML Milan City Hub

Despite intense competition, small and medium-sized manufacturing companies (SMEs) have successfully established themselves in various markets. One example is control and switchgear manufacturing. Control and switchgear cabinets are critical components in many applications, including industrial automation, power distribution, and complex machinery.
High-quality cabinets are crucial to the energy evolution towards sustainability through decentralised green energy generation and distribution, electromobility and charging infrastructure. SMEs in control cabinet manufacturing mainly produce specialised equipment in small batches. Their key competitive advantage is the specialised knowledge and expertise of their skilled workforce. This is why, at a time when skilled workers are in short supply, the introduction of automation solutions for repetitive tasks is essential.

Electronic waste challenges

As the performance requirements of electronic devices increase, so does the demand for new devices, resulting in a growing number of discarded devices. The amount of e-waste generated worldwide has increased by 33.8% over the past eight years from 44.4 million tons to approximately 59.4 million tons and is expected to rise by a further 26.3 % to approximately 75 million tons by 2030[1].
Potential recycling processes vary depending on the complexity and size of the equipment. While small circuits are mechanically shredded, larger devices, such as control cabinets, require manual disassembly. This approach not only drives up raw material extraction costs in high-cost countries but also consumes valuable human resources.

Creating a new business model through sustainability and supply chain resilience

Mangelberger Elektrotechnik GmbH, a control cabinet and electrical engineering company based in Germany, is taking an innovative approach to turning sustainability requirements into a new business model. This approach is based on the principles of reuse, remanufacturing, and recycling. The environmental footprint of electrical products is strongly determined by their raw materials[2]. Implementing a circular economy approach that focuses on recycling and reuse significantly reduces this impact.

- **Reuse:** Multiple use allows components, such as top hat rails, aluminium and copper busbars and metal frames to be directly reused, eliminating the need to manufacture new components. This not only reduces costs but also minimises the environmental impact associated with manufacturing new materials.
- **Remanufacturing:** By integrating advanced technologies, components can be returned to their original condition to ensure they meet the necessary quality standards for reintroduction into the production cycle. This approach reduces waste and dependence on new component supplies.
- **Recycling:** Plastics in the form of cable trays, fasteners, or covers are returned for granulation, a process that converts them into usable raw materials that can be recycled by partner companies.

This proposed circular economy concept offers not only environmental benefits but also economic ones. However, it is not just about the sale of recycled materials, which is the last possible recycling stream, particularly for scrap metal that cannot be reused in its current state. A key aspect driving the need for this innovative approach is the continuous and significant increase in the price of metal, electrical and electronic components in recent years[3]. The cost increase can be offset by reusing remanufactured components. This allows Mangelberger Elektrotechnik to offer the control cabinet as a circular product with a significant cost advantage for the customer.

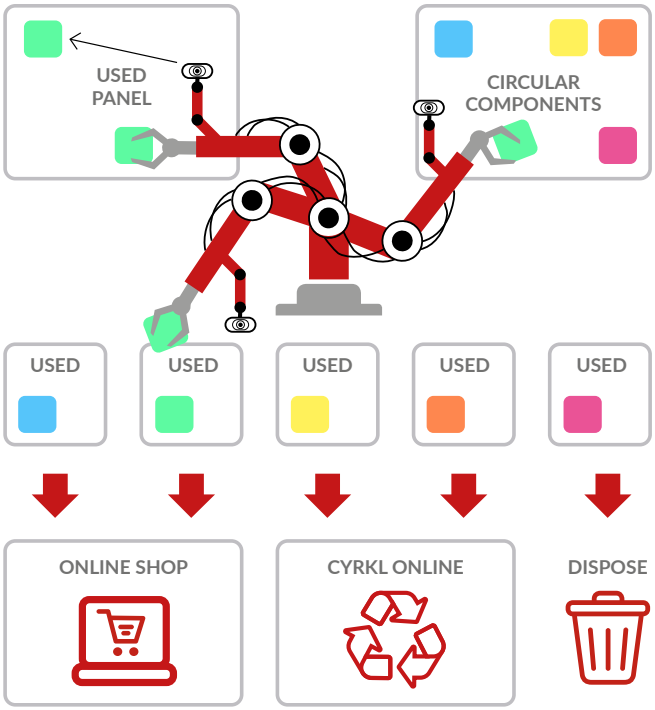
In addition to price increases, the availability of many components has become a major issue. Extensive industry surveys have highlighted the need for more resilient supply chains for electrical and electronic components. In particular, during the global COVID-19 pandemic, electrical component supply shortages and production stoppages occurred worldwide. However, unlike competitors with traditional business models, the circular business model enabled the company to leverage the components

contained in the recovered end-of-life equipment, thereby increasing supply capability. Overall, the change in business model offers not only environmental but also economic benefits and a more resilient supply chain.

Technological implications and socio-economic significance

The problem of e-waste is strongly perceived by the public due to its direct impact on the end consumer, which also leads to a high acceptance of the described recycling model by the customers due to the lower investment, the resulting lower ecological footprint as well as the advertising effect on the end consumer. To make the business model economically sustainable in the future, the research project "ARKIDES", which is funded by the German Federal Ministry of Economics and Climate Protection and scientifically supported by the Institute for Factory Automation and Production Systems (FAPS) in Nuremberg, is working on the further integration of automation into the batch size 1 disassembly and raw material selection process. This is an important step towards intelligent and automated recycling systems in high-cost countries. Technologically, the circular business model is based on the introduction of innovative technologies such as:

- **Reusable Component Knowledge Base:** A framework that documents reusable electrical and electronic components, features relevant to the automated disassembly process, and their safety testing processes to optimise component reuse.
- **Expert system for control and switchgear design:** Design rules can be established that consider automated manufacturing, assembly, disassembly, and raw material selection.
- **Machine learning component recognition:** Computer vision to identify specific components, fasteners, and raw material compositions to increase the efficiency and degree of automation of the reuse process.
- **Automated disassembly planning and execution:** Implementing hardware and software automation solutions can revolutionise the approach to the disassembly and sorting process, reducing manual labour and increasing accuracy.



One of the major advantages of the proposed solution is the use of existing technical equipment and workstations that were originally designed for assembly processes and are used for this purpose as part of normal operations. Disassembly tasks can be performed during non-working hours, ensuring optimal utilisation without taking up regular operating capacity.

Conclusion

The emphasis on a circular economy, coupled with an innovative business model that emphasises reuse, remanufacturing and recycling, ensures that the industry can thrive sustainably. This approach not only addresses environmental concerns, but also strengthens the supply chain and positions companies for long-term success in an ever-evolving global marketplace. The adaptive and learning aspects utilised in addressing the high variability of e-waste enable the developed solutions to be adaptable to different types of e-waste and equipment, thus expanding the scope and impact of these innovations. Additionally, technology licensing could be a feasible future stream of revenue for the business model.

References

1 *Forti, V., Baldé, C. P., Kuehr, R., & Bel, G. (2020). The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. Retrieved from https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf.*

2 *Hischier, R., Reale, F., Castellani, V., & Sala, S. (2020). Environmental impacts of household appliances in Europe and scenarios for their impact reduction. Journal of Cleaner Production, 267, 121952. https://doi.org/10.1016/j.jclepro.2020.121952.*

3 *Winzenick, M. (2023). Statistical Annual Report 2022. Retrieved from https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2023/Juni/ZVEI-Aussenhandelsreport_Juni_2023/ZVEI-Foreign-Trade-Report-June-2023.pdf .*

Addressing Sustainability Goals through Deep Tech-Driven Business Models: A Collaborative Approach to Innovation in Manufacturing

Emanuele Della Corte
Process Automation Engineer, Eli Lilly and Company - YML Milan City Hub

The challenges currently confronting humankind are unparalleled in their complexity and scope, demanding solutions of matching magnitude and sophistication. The year 2023 marked the turning point for the 2030 deadline of the United Nations' Sustainable Development Goals (SDGs), a set of 17 guiding principles aimed at fostering global peace and prosperity for both humanity and the environment. However, the latest report indicates inadequate and insufficient progress toward these goals[1]. The SDGs not only serve as a beacon for envisioning a more equitable world but also function as a critical handbook, offering guidance to redirect and realign our trajectory away from deep-seated inequalities and societal fragmentations.

Being responsible for approximately a quarter of the world's carbon emissions[2], the companies operating within the manufacturing and production sectors find themselves under increasing pressure to proactively reverse this alarming trend. However, the drivers for change extend beyond sustainability concerns alone. Goal 9 of the SDGs, which encompasses industry, innovation and infrastructure matters, highlights the fact that the global manufacturing sector experienced a notable deceleration, plummeting from a robust growth rate of 7.4% in 2021 to a mere 3.3% in 2022[3]. The downturn is attributed to a convergence of factors, including inflation, energy price shocks, supply chain disruptions, and the broader global economic slowdown. Manufacturing companies must adapt to the volatility of the global economy by investing in agile, resilient, and environmentally and socially sustainable solutions. Meeting this challenge can be achieved through the application of innovative business models based on the concept of "deep tech": a problems-oriented approach that leverages disruptive innovations to tackle large-scale issues[4].

The "Deep-Tech" approach

The deep-tech approach emerges within the framework of what can be referred to as the fourth wave of innovation, characterised by collaborative clusters comprising start-ups, venture capitalists, research centres, universities and end-users working in concert to expedite the deployment of innovative solutions[5]. An innovative deep tech-driven business model can spring from the cooperative synergy among key partners. Establishing a platform where consumers and producers collaborate for the successful implementation of the solutions can enhance both the speed and quality of the solutions developed by the clusters. An illustrative case of such collaboration is exemplified by FREYR, a start-up dedicated to the decarbonisation of transportation and energy systems through the development of clean, high-density, and high-quality battery cells. FREYR actively participates in a cluster based in northern Europe, in partnership with EIT InnoEnergy, with a shared mission to optimise research and fortify the supply chain. Amongst its notable collaborators, FREYR has forged partnerships with prestigious entities such as the Norwegian University of Science and Technology, Siemens, and Honeywell. These partnerships exemplify a shift from a business modelling in which value creation focuses on shareholders to a model where partners function as stakeholders. In this evolved approach, stakeholders do not necessarily own company stocks, but are invested in the long-term success of the project in which they are involved.

Moreover, working with stakeholders with a problem-oriented approach allows innovation to be directed to precisely where it is most crucial, guided by robust prioritisation and the engagement of a skilled workforce. The value proposition of deep-tech business models hinges on disruptive innovations, establishing its foundations upon cutting-edge technologies and unveiling their potential even before widespread recognition. The latest World Economic Forum report on emerging technologies emphasises that future innovations will be increasingly driven by the creative convergence between the physical and digital domains[6]. Consequently, it can be assumed that deep-tech companies will exploit these technologies to an even greater extent in the near future.

Among these emerging technologies, the utilisation of Artificial intelligence and the Metaverse for product design

and innovation acceleration represents a pioneering approach to innovation. Notably, Siemens and NVIDIA have recently announced a partnership aimed at merging the industrial ecosystem of Siemens Xcelerator with NVIDIA Omniverse, an AI-powered, real-time, and physics-based platform. This collaboration aims to create an industrial metaverse, capable of virtualising processes from the edge to the cloud, thus providing a virtual platform to address real-world challenges. Siemens Xcelerator serves as a compelling exemplar of successful collaboration within the industrial market. It is an open ecosystem that enables partnerships among customers, Siemens, and certified partners, including independent software developers. Within this platform, the fundamental idea of the deep-tech business model is readily discernible. The underpinnings of a business model are associated with its economic resilience and meaningfulness; the cost structure must be solid and the revenue streams well defined.

A report published by the Boston Consulting Group underscores that deep-tech products often entail a cost premium ranging from 30% to 240% when compared to existing market alternatives[7], thereby presenting manufacturing leaders with a perplexing dilemma. Encouragingly, the report also reveals a declining trajectory in the unit costs of deep-tech solutions over time. Furthermore, embracing cutting-edge technological advancements, especially when co-financed through public or private funds, yields a significantly higher return on investment compared to the alternative of exposing the business to the risk of lagging behind competitors' disruptive innovations. This underscores the imperative of staying at the forefront of technological progress in the pursuit of sustainable and competitive business models.

Conclusion

The approach of the deep tech-driven business models in the new era of manufacturing relies on the interplay between the needs of humanity and machine capabilities. The human element in the implementation of such innovative business models represents the invaluable factor that can propel technological advancements to their maximum potential. Keywords such as cooperation, openness, and sustainability invigorate individuals, inspiring them to strive for excellence, imbuing their work with purpose, and giving research and development an even deeper significance. Following this path, the "New Era of Manufacturing" can be defined by groundbreaking technologies that enable us to achieve our social and environmental sustainability goals.

References

1 *The Sustainable Development Goals Report (2023), Retrieved from https://unstats.un.org/sdgs/?aspxerrorpath=/sdgs/report/2023.*

2 *Liu, Z., Deng, Z., Davis, S. et al. Monitoring global carbon emissions in 2022. Nat Rev Earth Environ 4, 205–206 (2023). Retrieved from https://doi.org/10.1038/s43017-023-00406-z.*

3 *Ibid. 1*

4 *de la Tour A., Portincaso M., Blank K., Goeldel N., Aré L., Tallec C., Gourévitch A., Pedroza S., The Dawn of the Deep Tech Ecosystem (2019) Retrieved from https://media-publications.bcg.com/BCG-The-Dawn-of-the-Deep-Tech-Ecosystem-Mar-2019.pdf*

5 *de la Tour A., Portincaso M., Goeldel N., Chaudhry U., Tallec C., Gourévitch A., Deep Tech: The Great Wave of Innovation (2021) Retrieved from https://hello-tomorrow.org/wp-content/uploads/2021/01/BCG_Hello_Tomorrow_Great-Wave.pdf .*

6 *Top 10 Emerging Technologies of 2023 (2023, June) Retrieved from https://www.weforum.org/reports/top-10-emerging-technologies-of-2023.*

7 *Bobier J.F., Goeldel N., Paschkewitz J., Gross-Selbeck S., Gourévitch A., and Coulin A.D., Deep Tech Powers New Net-Zero Business Models (2022, November 01) Retrieved from https://www.bcg.com/publications/2022/advanced-tech-powers-new-net-zero-business-model.*

Achieving Sustainable and Resilient Business Models Through Three Strategic Shifts

Sandra Jaksic
Master's degree student, Chalmers University of Technology – YML Gothenburg City Hub

In the "New Era of Manufacturing", the impact of megatrends is reshaping the industry, compelling manufacturers to rethink their business models. These megatrends include shifts in values, environmental consciousness, health and ageing considerations, equality, and globalisation and the need for community.

Customers now demand transparency, diversity, individualisation, and eco-consciousness. They seek products and services that align with their values and lifestyles. This essay explores how manufacturers respond to these megatrends through three important shifts: the Service Shift, the Digital Shift, and the Circular Shift. These transformations exemplify the industry's adaptation to a changing world.

The Service Shift

The service shift represents a transition from the conventional product-centric approach to one that is customer-centric. This change entails moving beyond the mere sale of products towards providing comprehensive solutions. It involves a fundamental reorientation – shifting the focus from internal processes to the customer's processes and where value truly emerges. Thus, companies need to support customers throughout their value creation process and let the customer take a central role in the creation and delivery of value.
For instance, consider Rolls-Royce's remarkable transition towards servitisation. Specialising in jet engines for the aviation sector, Rolls-Royce utilised technological advancements to enhance engine durability and lifespan. Using a digital electronic control system, they gathered crucial data on engine parameters, proactively protecting engine components. However, this improvement in product longevity created an unexpected challenge. With engines lasting longer, the demand for spare parts decreased, resulting in revenue loss. In response, Rolls-Royce introduced an integrated solution, "Power by the hour", which offered a fixed-price maintenance plan linked to engine availability. This innovative approach marked a great shift in their business model, with customers paying based on actual engine usage.

Servitisation creates increased customer engagement, forging deeper relationships while generating recurring revenue streams. Moreover, this shift aligns with sustainability objectives by minimising waste and extending product lifecycles. It encourages customisation, empowering customers to tailor solutions to their unique needs, ultimately providing competitive edge, particularly when competing with low-cost production in other countries. In this transformed business model, offering products as services becomes a strategic advantage, highlighting the manufacturer's role as a provider of value-driven, sustainable solutions.

The Digital Shift

The Digital Shift involves the integration of digital technologies into business operations. Key components include digital twins, for the creation of virtual replicas for real-time monitoring and optimisation; Artificial Intelligence (AI), for the automation of tasks and improvement of decision-making; Internet of Things (IoT), for connecting physical devices for data exchange; robotics for automation; and Big Data and Analytics for process optimisation and predictive maintenance. This shift enhances efficiency, quality, and real-time decision-making, making manufacturing more agile and competitive. Take Siemens Electronics Works Amberg (EWA), for example. EWA manufactures a diverse range of products, including PLCs. Their focus on digital twins, AI, robotics, Big Data and Analytics has propelled them to the forefront of technological innovation. With 75% of their value chain automated and handled by machines and robots, they maintain a 99.9999% daily quality. Since 1990, EWA has achieved a 14-fold increase in productivity and a 140% rise in factory output without an increase in resource consumption or energy usage, even as product complexity has doubled. Their innovative use of blockchain technology addressed the challenge of determining a product's true carbon footprint, promoting a more sustainable and transparent supply chain ecosystem. An example of the benefits of digital technologies could be seen during the COVID-19 pandemic. EWA's robust digitalisation and automation infrastructure gave almost

real-time insight into the processes and enabled remote assistance, effectively mitigating the pandemic's impact on productivity.

The impact of the digital shift on manufacturing is evident through EWA's success. Digital technologies not only enhance sustainability through reduced resource consumption but also improve resilience by enabling agile responses to disruptions, as exemplified during the COVID-19 pandemic. Furthermore, these technologies significantly enhance competitiveness by streamlining operations and optimising productivity. This digital transformation reflects the industry's capacity to redefine itself, emphasising sustainability, adaptability, and a competitive edge in a dynamic market environment.

The Circular Shift

The circular shift in manufacturing represents a transition from traditional linear production models. Circular business models emphasise resource efficiency, aiming to minimise resource consumption and maximise material utilisation. These models encourage recycling and reuse by ensuring products that are easily disassembled, recycled or repurposed. Sustainable supply chains are established through responsible material sourcing and reduced carbon footprints. This shift also promotes the transition from selling products to offering services, thereby prolonging product longevity and reusability. Repair and maintenance services are prioritised to extend product lifespans.

Consider IKEA, a multinational furniture retailer with the goal of becoming circular and climate positive by 2030. Starting with the product design stage, they have undertaken several circular initiatives, which now have an increased focus on reusability, refurbishment, remanufacturing, and recycling. For instance, they've redesigned their best-selling product to reduce plastic usage by incorporating renewable materials and use snap fittings instead of nails for easy disassembly and repair. They also have a mattress recycling initiative that has helped reduce waste in landfills by repurposing discarded mattresses. To maintain the value of the products and materials, IKEA has established a service promoting product care, maintenance, and upgrades. Customers can order assembly parts to prolong product lifespan, with plans to offer furniture spare parts. In some locations, like IKEA Poland, sofa repair and refurbishment services are already available. These initiatives exemplify the potential to prolong the product lifespan.

Circular practices not only reduce the environmental impact and enhance resource efficiency, but they also create supply chain resilience. By minimising dependence on finite resources, and implementing recycling and remanufacturing processes, it is possible to create a flexible and adaptable supply chain, capable of withstanding disruptions. These practices mitigate vulnerability to resource scarcity and price fluctuations, ultimately enhancing a manufacturer's competitiveness in a dynamic marketplace.

Conclusion

The service, digital and circular shifts represent a pivotal transformation in the manufacturing industry. These shifts are interrelated and complementary, enabling manufacturers to respond to megatrends and evolving customer demands effectively. They bridge the gap between customer-centricity, digital innovation and sustainable practices. The question is no longer whether manufacturers should embrace these changes but how swiftly they can do so. These shifts aren't just strategic tools; they are the keys to a thriving and sustainable future.

References

1 *Owen, C., Stephan, U. and Perry, A. (2017), Megatrends are driving opportunities for business growth through advanced services, Noventum.*

2 *Smith, David. (2013). Power-by-the-hour: The role of technology in reshaping business strategy at Rolls-Royce. Technology Analysis and Strategic Management. 25. 987-1007. 10.1080/09537325.2013.823147.*

3 *Capgemini Research Institute. (2021). Intelligent Industry: The Next Era of Transformation. Conversations for Tomorrow, 3, 65–73.*

4 *IKEA. (n.d.). IKEA Sustainability Report FY22.*

Reshaping Manufacturing Business Models: A Holistic Approach Towards Sustainability

Aikaterini Paraskevopoulou
Master's Student, Laboratory for Manufacturing Systems & Automation (LMS), University of Patras - Patras City Hub

In today's world, manufacturers are facing a plethora of challenges that are prompting them to rethink their fundamental business models. Such challenges are driven by profound changes in technology, society, and the environment. These forces are compelling manufacturers to reevaluate their operations, strategies, and core principles, necessitating a fundamental transformation in how they conduct business.

This essay delves into the key trends motivating manufacturers to embark on this transformation, with a deep focus on economic, social, and environmental sustainability. Additionally, it explores how digital technologies are at the forefront of this transformation, ushering in a "New Era of Manufacturing". In the following paragraphs, the strategies and approaches that empower manufacturers to thrive in an ever-changing world while staying committed to sustainability will be explored though a holistic point of view. This involves embracing economic sustainability through streamlined processes, ensuring social sustainability by promoting ethical practices, and fostering environmental sustainability via eco-friendly operations. Digital technologies are facilitating this transition, enabling efficiency and innovation while anchoring the entire approach in the "New Era of Manufacturing". A comprehensive strategy that considers these multi-dimensional aspects is crucial to crafting business models that are resilient, competitive, and inherently sustainable. These trends should not be considered as separate entities but rather as a collective force reshaping the manufacturing landscape.

The arrival of Industry 4.0 marked the beginning of a new era in manufacturing. This trend is characterised by the integration of digital technologies, automation, and data analytics[1].

Manufacturers are re-evaluating their business models to harness the benefits of these technologies. Central to this shift is the increased use of smart products that incorporate Internet of Things (IoT) and sensor technologies, enabling manufacturers to gather data from customers and offer enhanced features and services. Automation and data analytics are used to optimise the supply chain, which lowers costs and increases reliability. In addition, collaborative ecosystems have developed as a result of manufacturers forming alliances and collaborations and sharing information, resources, and capabilities to benefit consumers and stakeholders in this dynamic Industry 4.0 environment. The groundwork established during Industry 4.0 has prepared the path for Industry 5.0 which encompasses not only digitalisation but also Sustainability, Human-centricity and Resilience.

Sustainability, which includes both the environmental, social, and economic dimension, is a core driver of business model re-evaluation[2]. Manufacturers are adopting sustainable practices to reduce their carbon footprint and address ethical and social responsibility. Economic sustainability is promoted by minimising waste and operational costs. Social sustainability involves fair labour practices, diversity, and community engagement. Digital technologies enable manufacturers to track and optimise their sustainability initiatives, ensuring they remain aligned with business goals.

Furthermore, policy initiatives, like the European Green Deal, compel manufacturers to align with stringent environmental goals and improve their business models to meet ambitious sustainability targets. Business model innovation fosters economic sustainability by ensuring compliance and adapting to a changing regulatory landscape. Social sustainability is addressed through ensuring 'no place and no person is left behind', and environmental sustainability by reducing carbon emissions and enhancing eco-friendly manufacturing. Digital technologies provide the tools for monitoring and optimising sustainability efforts, supporting compliance with ambitious environmental standards.

Circular economy principles are also gaining ground as a response to mounting environmental concerns. Manufacturers are rethinking and redesigning products with reuse, recycling, and resource efficiency in mind. This

shift contributes to economic sustainability by reducing resource consumption and waste[3]. Social sustainability is achieved by fostering a culture of responsible consumption and reuse and recycling. On the environmental front, it mitigates the environmental footprint of manufacturing processes by reducing waste generation and conserving resources. Digital technologies play a crucial role in tracking materials and products throughout their lifecycle, ensuring they remain in circulation and out of landfills.

Recent disruptions have also highlighted the importance of resilient supply chains[4]. Manufacturers are rethinking their business models by diversifying suppliers, regionalising production, and enhancing logistics. This approach ensures economic sustainability by mitigating risks associated with supply chain disruptions. Social sustainability is addressed by preserving employment opportunities. In terms of the environment, this is accomplished by optimising transportation and reducing emissions through streamlined supply chain operations. Digital technologies provide real-time supply chain visibility and predictive analytics, enhancing resilience.

On the other hand, globalisation is still driving manufacturers to adapt their business models[5] to expand into diverse markets, navigate various regulatory environments, and meet the demands of culturally diverse consumers. This trend promotes economic sustainability through market expansion, while socially, it necessitates sensitivity to cultural diversities and local labour practices. From an environmental perspective, it focuses on responsible global sourcing and sustainable manufacturing practices. Digital technologies facilitate communication across borders, track international operations, and enable real-time adaptation to global market dynamics.

Several leading companies, like Tesla, Inc., exemplify the transformative power of trends reshaping manufacturing. Tesla's business model centres on electric vehicles (EVs) and sustainable energy solutions. They have revolutionised the automotive industry by pioneering EVs, reducing carbon emissions, and promoting sustainability. Through online sales, strong customer relationships, and diverse revenue streams, including EV sales, energy storage, and software upgrades, they have set new standards for digital integration in manufacturing, leveraging technologies like data analytics and AI.

Siemens, embracing Industry 4.0's digitalisation and automation, is leading the way in sustainable manufacturing. Their business model centres on digital technologies, optimising energy efficiency and reducing their environmental footprint. Through innovative solutions, like digital twin technology, they create virtual replicas of physical assets, enhancing product design and manufacturing processes. This approach aligns with their diverse customer segments, which range from industrial clients to those seeking energy-efficient solutions. Siemens' commitment to environmental responsibility, robust technological resources, and innovative collaborations reshapes the manufacturing landscape, underscoring their leadership in the Industry 4.0 era.

Volvo's "Volvo Reman" programme exemplifies a seamless alignment with their business model canvas, underscoring their core values of sustainability and innovation. This initiative, focused on remanufacturing components and parts from used vehicles, extends product lifespans and significantly reduces waste, resonating with environmentally conscious consumers and cost-conscious businesses. By refurbishing and upgrading components to like-new condition, Volvo not only contributes to their revenue streams but also demonstrates their commitment to sustainability. Furthermore, the integration of digital technologies, such as IoT sensors and data analytics, enhances the efficiency of the process by enabling real-time monitoring and predictive maintenance. This blend of circular economy principles and digital technologies reinforces Volvo's dedication to reducing waste, offering eco-friendly solutions, and fostering strong customer relationships built on sustainability.

As shown by the three exemplary case studies reported above, digital technologies play a crucial role in this

transformative "New Era of Manufacturing". These technologies do not just assist but ignite entirely new business paradigms, fuelling efficiency, personalisation, sustainability, and unwavering transparency. With these tools in hand, manufacturers can wholeheartedly embrace a comprehensive reimagining of their models, where economic strength unites with social responsibility and environmental consciousness. In this way, their unyielding dedication to sustainability will reverberate through every facet of their enterprise, leaving an indelible mark on the future of industry. This accentuates the dawn of a momentous era, one where sustainability is the very essence of manufacturing's new identity, steering it towards a future that is not just adaptive but thriving.

References

1 *Mamad Mohamed, "Challenges and Benefits of Industry 4.0: An Overview," International Journal of Supply and Operations Management 5, no. 3 (2018): 256–65.*

2 *Vasiliki C Panagiotopoulou and Panagiotis Stavropoulos, "On the Sustainability Indexing of Carbon Footprint Reduction Approaches for Manufacturing Industry," in Proceedings of the Changeable, Agile, Reconfigurable and Virtual Production Conference and the World Mass Customization & Personalization Conference (Springer, 2023), 404–12.*

3 *Simone Sehnem et al., "Circular Economy: Benefits, Impacts and Overlapping," Supply Chain Management 24, no. 6 (2019): 784–804, https://doi.org/10.1108/SCM-06-2018-0213.*

4 *Emmanuel Sawyerr and Christian Harrison, "Developing Resilient Supply Chains: Lessons from High-Reliability Organisations," Supply Chain Management 25, no. 1 (2020): 77–100, https://doi.org/10.1108/SCM-09-2018-0329 .*

5 *Yongho Lee, Juneseuk Shin, and Yongtae Park, "The Changing Pattern of SME's Innovativeness through Business Model Globalization," Technological Forecasting and Social Change 79, no. 5 (2012): 832–42, https://www.sciencedirect.com/science/article/abs/pii/S0040162511002228.*

References

1 *Ricart, J., and Casadesus-Masanell, R. (2011). How to Design a Winning Business Model. Harvard Business Review, 89(1-2):100–107.*

2 *Mitchell, D., and Coles, C. (2003). The Ultimate Competitive Advantage of Continuing Business Model Innovation. Journal of Business Strategy, 24(5):15-21.*

3 *Teece, D.J. (2010). Business Models, Business Strategy and Innovation. Long Range Plan, 43(2-3):172-194.*

4 *Osterwalder, A., and Pigneur, Y. (2010). Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers, John Wiley & Sons.*

5 *Foss, N.J., and Saebi, T. (2017). Business Models and Business Model Innovation: Between Wicked and Paradigmatic Problems. Long Range Plan, 51(1):9-21.*

6 *Clauss, T. (2017). Measuring Business Model Innovation: Conceptualization, Scale Development, and Proof of Performance. R&D Management, 47(3):385-403.*

7 *EY (2022). Why Industrial Companies Need To Lead Business Model Innovation. https://www.ey.com/en_gl/advanced-manufacturing/why-industrial-companies-need-to-lead-business-model-innovation*

8 *Bocken, N.M.P., Short, S.W., Rana, P., and Evans, S. (2014). A Literature and Practice Review to Develop Sustainable Business Model Archetypes. Journal of Cleaner Production, 65:42-56.*

9 *Taran, Y., Boer, H., and Lindgren, P. (2015). A Business Model Innovation Typology. Decision Sciences, 46(2):301-331.*

10 *Achtenhagen, L., Melin, L., and Naldi, L. (2013). Dynamics of Business Models—Strategizing, Critical Capabilities and Activities for Sustained Value Creation. Long Range Planning, 46(6):427-442.*

11 *Magretta, J. (2022). Why Business Models Matter. Harvard Business Review, 80:86-92.*

12 *Zott, C., Amit, R., and Massa, L. (2011). The Business Model: Recent Developments and Future Research. Journal of Management, 37(4):1019-1042.*

13 *Schneider, S., and Spieth, P. (2013). Business Model Innovation: Towards an Integrated Future Research Agenda. International Journal of Innovation Management, 17(1):755-756.*

14 *Koen, P.A., Bertels, H.M.J., and Elsum, I.R. (2011). The Three Faces of Business Model Innovation: Challenges for Established Firms, Research-Technology Management, 54(3):52-59.*

15 *Eppler, M.J., and Hoffmann, F. (2014). Strategies for Business Model Innovation: Challenges and Visual Solutions for Strategic Business Model Innovation, Strategy and Communication for Innovation, 3-13.*

16 *Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. International Journal of Production Economics, 210, 15-26.*

17 *Precedence Research. (2023). Digital Transformation Market. Retrieved from https://www.precedenceresearch.com/digital-transformation-market*

18 *Deloitte (2023). 2023 manufacturing industry outlook. Retrieved from https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/manufacturing-industry-outlook.html*

19 *Mordor Intelligence Private Limited. (2023). Digital Transformation in Manufacturing Market Revenues to Reach USD 733.75 billion by 2028 - Market Size, Share, Forecasts, & Trends Analysis Report. Retrieved from https://www.mordorintelligence.com/industry-reports/digital-transformation-market-in-manufacturing/market-size*

20 *Frank, A. G., Mendes, G. H., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. Technological Forecasting and Social Change, 141, 341-351.*

21 *Meindl, B., Ayala, N. F., Mendonça, J., & Frank, A. G. (2021). The four smarts of Industry 4.0: Evolution of ten years of research and future perspectives. Technological Forecasting and Social Change, 168, 120784.*

22 *WEG website: https://www.weg.net/institutional/US/en/solutions/digital-solutions/mfm*

23 *WEG website: https://www.weg.net/catalog/weg/BR/en/Digital-Solutions/Artificial-Intelligence/c/BR_WDC_DIGITAL_AI*

24 *WEG website: https://www.weg.net/institutional/BR/pt/news/produtos-e-solucoes/weg-v2com-abdi-e-anatel-concluem-relatorio-da-segunda-fase-do-projeto-open-lab-5g*

25 *Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie, 4(0), 82.*

26 *Volpe Rodrigues, T., dos Santos Filho, V. H., Pontes, J., Martins de Resende, L. M., & Tadashi Yoshino, R. (2021). Goverment initiatives 4.0: a comparison between industrial innovation policies for industry 4.0. Gestão e Desenvolvimento (18075436), 18(1).*

27 *Ranking Reveals Models for Industrial Digitalization. BloombergNEF Blog. https://about.bnef.com/blog/bloombergnefs-country-ranking-reveals-models-industrial-digitalization/*

28 *OECD (2021).The Digital Transformation of SMEs. Report.03 Feb 2021, 275 pages. https://doi.org/10.1787/bdb9256a-en*

29 *https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/transformacaodigital/arquivo-camara-industria/ci-reuniao-ro-10-30_08_2022_anexo4_white-paper-i4-0-for-smes-brazil.pdf*

30 *Ibid.*

31 *MIT report: https://workofthefuture.mit.edu/research-post/the-work-of-the-future-building-better-jobs-in-an-age-of-intelligent-machines/*

32 *Frank, A.G., Ayala, N., Benitez, G., Marcon, E., Lerman, L. Profissões emergentes na era digital. In: https://static.portaldaindustria.com.br/media/filer_public/b7/5a/b75af326-9c36-49e7-b298-1b9f0a3d4938/estudo_profissoes_emergentes_-_giz_ufrgs_e_senai.pdf*

33 *Feijão, C., Flanagan, I., Stolk, C. van., Gunashekar, S. (2021). The global digital skills gap. In: https://www.rand.org/content/dam/rand/pubs/research_reports/RRA1500/RRA1533-1/RAND_RRA1533-1.pdf*

34 *https://www.unep.org/regions/asia-and-pacific/regional-initiatives/supporting-resource-efficiency/green-economy*

35 *https://www.kbvresearch.com/green-technology-and-sustainability-market/*

36 *Brownlow, J., Zaki, M., Neely, A., Urmetzer, F., & others. (2015). Data and analytics-data-driven business models: A Blueprint for Innovation. Cambridge Service Alliance, 7(February), 1–17.*

37 *Harvard Business Review Analytics Survey. (2022). Transforming Data into Business Value through Analytics and AI. Harvard Business Review. https://hbr.org/sponsored/2023/03/transforming-data-into-business-value-through-analytics-and-ai?autocomplete=true*

38 *Hartmann, P., Zaki, M., Feldmann, N., & Neely, A. (2014). Big data for big business? A taxonomy of data-driven business models used by start-up firms*

39 *Kühne, B., & Böhmann, T. (2018). Requirements for representing data-driven business models-towards extending the business model canvas*

40 *Bulger, M., Taylor, G., & Schroeder, R. (2014). Data-driven business models: Challenges and opportunities of big data. Oxford Internet Institute. Research Councils UK: NEMODE, New Economic Models in the Digital Economy*

41 *https://www.precedenceresearch.com/customization/3090, Dhapte, Aarti. 07/2023. "Artificial Intelligence (AI) In Manufacturing Market." 07/2023. https://www.marketresearchfuture.com/reports/artificial-intelligence-ai-in-manufacturing-market-7745.)*

42 *Bughin, Jacques, et al. "Notes from the AI frontier: Modeling the impact of AI on the world economy." McKinsey Global Institute 4 (2018).*

43 *"Country Spotlights: Why Artificial Intelligence Is the Future of Growth" (Accenture, 2016), 8.*

44 *Burström, Thommie, et al. 'AI-Enabled Business-Model Innovation and Transformation in Industrial Ecosystems: A Framework, Model and Outline for Further Research'. Journal of Business Research, vol. 127, Elsevier BV, Apr. 2021, pp. 85–95, https://doi.org10.1016/j.jbusres.2021.01.016*

45 *Kohtamäki, Marko, et al. "Digital servitization business models in ecosystems: A theory of the firm." Journal of Business Research 104 (2019): 380-392*

46 *Daniel Castro and Joshua New, "The Promise of Artificial Intelligence" (Center for Data Innovation, October 2016), 2*

47 *Stephen Ezell, "Why Manufacturing Digitalization Matters and How Countries Are Supporting It" (Information Technology and Innovation Foundation, April 2018)*

48 *Sjödin, David, et al. "How AI capabilities enable business model innovation: Scaling AI through co-evolutionary processes and feedback loops." Journal of Business Research 134 (2021): 574-587*

49 *"The New Production Workforce: Responding to Shifting Labour Demands" (Accenture and The World Economic Forum, January 2018), 4, 13.*

50 *https://www.ibm.com/downloads/cas/GVAGA3JP*

51 *Fox, John. "Expert systems and theories of knowledge." Artificial intelligence. Academic Press, 1996. 157-181*

52 *Hasgül, Servet, et al. "Project-oriented task scheduling for mobile robot team." Journal of Intelligent Manufacturing 20 (2009): 151-15*

53 *Chryssolouris, G., K. Dicke, and M. Lee. "An approach to short interval scheduling for discrete parts manufacturing." International Journal of Computer Integrated Manufacturing 4.3 (1991): 157-168.*

54 *Chryssolouris, G., Dicke, K., & Lee, M. (1992). On the resources allocation problem. The International Journal of Production Research, 30(12), 2773-2795*

References

55 *Chryssolouris, G., J. Pierce, and K. Dicke. "An approach for allocating manufacturing resources to production tasks." Journal of Manufacturing Systems 10.5 (1991): 368-382*

56 *Kolisch, Rainer, and Andreas Drexl. "Adaptive search for solving hard project scheduling problems." Naval Research Logistics (NRL) 43.1 (1996): 23-40*

57 *Li, Ke Y., and Robert J. Willis. "An iterative scheduling technique for resource-constrained project scheduling." European Journal of Operational Research 56.3 (1992): 370-379*

58 *Chryssolouris, George, and Velusamy Subramaniam. "Dynamic scheduling of manufacturing job shops using extreme value theory." Production Planning & Control 11.2 (2000): 122-132*

59 *Chryssolouris, G., M. Lee, and M. Domroese. "The use of neural networks in determining operational policies for manufacturing systems." Journal of Manufacturing Systems 10.2 (1991): 166-175*

60 *Chryssolouris, George, and Velusamy Subramaniam. "Dynamic scheduling of manufacturing job shops using genetic algorithms." Journal of Intelligent Manufacturing 12 (2001): 281-293*

61 *Kádár, Botond, et al. "Enhanced control of complex production structures by tight coupling of the digital and the physical worlds." CIRP annals 59.1 (2010): 437-440*

62 *Twilio (2022) State of Customer Engagement Report. https://twilio-cms-prod.s3.amazonaws.com/documents/Twilio_SOCER_2022_EN.pdf*

63 *emplifi (2022). 87 percent of companies state they provide excellent CX, only 11 percent of customers agree. https://www.businesswire.com/news/home/20220121005224/en/87-percent-of-companies-state-they-provide-excellent-CX-only-11-percent-of-customers-agree*

64 *Salvador, Fabrizio, Pablo Martin De Holan, and Frank Piller. "Cracking the code of mass customization." MIT Sloan management review (2009)*

65 *Deloitte, 2019. The Deloitte Consumer Review Made-to-order: The rise of mass personalization, Online, https://www2.deloitte.com/ch/en/pages/consumer-business/articles/made-to-order-the-rise-of-mass-personalisation.html.*

66 *Andersson, the Long Tail: Why the Future of Business Is Selling Less of More (2006)*

67 *Coresight Research (2022). Retail Personalization in 2022: Balancing Trust, Data Collection and Privacy. https://coresight.com/research/retail-personalization-in-2022-balancing-trust-data-collection-and-privacy/*

68 *https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/the-value-of-getting-personalization-right-or-wrong-is-multiplying*

69 *Ibid.*

70 *Deloitte, 2019. The Deloitte Consumer Review Made-to-order: The rise of mass personalization, Online, https://www2.deloitte.com/ch/en/pages/consumer-business/articles/made-to-order-the-rise-of-mass-personalisation.html.*

71 *Ibid.*

72 *Piller, F.T. and Kumar, A. (2006) 'Mass customization: providing custom products and services with mass production efficiency', Journal of Financial Transformation, Vol. 18, No. 1, pp.25–31.*

73 *Lyons, A., Mondragon, C., Piller, F. et al. (2012) Customer-Driven Supply Chains From Glass Pipelines to Open Innovation Networks. Edited by R. Roy. Springer London.*

74 *Pine, B.J., Victor, B. and Boynton, A.C. (1993) 'Making mass customization work', Harvard Business Review, Vol. 71, No. 5, pp.108–119.*

75 *Mass Customization – The new Frontier in Business competition*

76 *Tseng, M. M. et Radke, A. M. (2011) 'Production Planning and Control for Mass Customization – A Review of Enabling Technologies', Springer Series in Advanced Manufacturing, 54, pp. 195–218.*

77 *MC study 2017, EU publications, https://ec.europa.eu/growth/publications/mass-customisation_en*

78 *https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/the-value-of-getting-personalization-right-or-wrong-is-multiplying#/*

79 *Salvador, F., de Holan, P. M. and Piller, F. T. (2009) 'Cracking the Code of Mass Customization', MIT Sloan Management Review, 50(3), pp. 71–78.*

80 *Jørgensen, K. A., Brunø, T. D., Taps, S. B., & Nielsen, K. (2014). Customization Issues: A Four-Level Customization Model. I Proceedings of the 7th World Conference on Mass Customization, Personalization, and Co-Creation (MCPC 2014) (s. 73-82). Springer. Lecture Notes in Production Engineering https://doi.org/10.1007/978-3-319-04271-8_7*

81 *Pine, B. Joseph, and James H. Gilmore. "The experience economy: past, present and future." Handbook on the experience economy 1 (2013): 21-44.*

82 *Moon, S. K., Simpson, T. W. et Kumara, S. R. T. (2009) 'An agent-based recommender system for developing customized families of products', Journal of Intelligent Manufacturing, 20(6), pp. 649–659.*

83 *Alfnes, E. and Strandhagen, J.O. (2010) 'Enterprise design for mass customisation: the control model methodology', International Journal of Logistics Research and Applications,*

84 *Frutos, J.D. and Borenstein, D. (2004) 'A framework to support customer – company interaction in mass customization environments', Computers in Industry, Vol. 54, No. 2, pp.115–135.*

85 *Jensen, K.S. and Svensson, K. (2004) 'Issues of mass customisation and supporting IT-solutions', Computers in Industry, Vol. 54, No. 1, pp.83–101.*

86 *Fogliatto, F. S., Da Silveira, G. J. C. et Borenstein, D. (2012) 'The mass customization decade: An updated review of the literature', International Journal of Production Economics, 138(1), pp. 14–25.*

87 *Olhager, J. (2010) 'The role of the customer order decoupling point in production and supply chain management', International Journal of Production Economics, Vol. 61, No. 9, pp.863–868.*

88 *Labarthe, O., Ferrarini, A., Espinasse, B. et al. (2006) 'Multi-agent modelling for simulation of customer-centric Supply Chain', International Journal of Simulation and Process Modelling, 2(3–4), pp. 150–163.*

89 *MacCarthy, B. (2013) An analysis of order fulfilment approaches for delivering variety and customisation, International Journal of Production Research, 51:23-24, 7329-7344*

90 *Walcher, D., & Piller, F. T. (2012). The customization 500: an international benchmark study on mass customization and personalization in consumer e-commerce. ICON Group International.*

91 *Ibid.*

92 *Neely A, Benedettini O, Visnjic I (2011) The servitization of manufacturing: further evidence. 18th Eur Oper Manag Assoc Conf 1.*

93 *Dachs B, Biege S, Borowiecki M, Lay G, Jäger A, Schartinger D (2014) Servitisation of European manufacturing: evidence from a large-scale database. Serv Ind J 34(1):5–23*

94 *Mastrogiacomo, L., Barravecchia, F., Franceschini, F. (2019). A worldwide survey on manufacturing servitization. Int J Adv Manuf Technol 103, 3927–3942*

95 *Pezzotta, G. et al. (2023). The Digital Servitization of Manufacturing Sector: Evidence from a Worldwide Digital Servitization Survey. In: Alfnes, E., Romsdal, A., Strandhagen, J.O., von Cieminski, G., Romero, D. (eds) Advances in Production Management Systems. Production Management Systems for Responsible Manufacturing, Service, and Logistics Futures. APMS 2023. IFIP Advances in Information and Communication Technology, vol 690. Springer, Cham*

96 *Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., ... & Wilson, H. (2007). State-of-the-art in product-service systems. Proceedings of the Institution of Mechanical Engineers, Part B: journal of engineering manufacture, 221(10), 1543-1552*

97 *Mont, O. K. (2002). Clarifying the concept of product–service system. Journal of cleaner production, 10(3), 237-245*

98 *Baines, T. S., Lightfoot, H. W., Benedettini, O., & Kay, J. M. (2009). The servitization of manufacturing: A review of literature and reflection on future challenges. Journal of manufacturing technology management, 20(5), 547-567*

99 *Mont, O. K. (2002). Clarifying the concept of product–service system. Journal of cleaner production, 10(3), 237-245*

100 *Tukker, A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Business strategy and the environment, 13(4), 246-260*

101 *Raddats, C., Kowalkowski, C., Benedettini, O., Burton, J., & Gebauer, H. (2019). Servitization: A contemporary thematic review of four major research streams. Industrial Marketing Management, 83, 207-223*

102 *Kamp, B., & Parry, G. (2017). Servitization and advanced business services as levers for competitiveness. Industrial marketing management, 60*

103 *Baines, T., & W. Lightfoot, H. (2013). Servitization of the manufacturing firm: Exploring the operations practices and technologies that deliver advanced services. International Journal of Operations & Production Management, 34(1), 2-35*

104 *Ibid.*

105 *Dinges, V., Urmetzer, F., Martínez, V., Zaki, M., & Neely, A. (2015). The future of servitization: Technologies that will make a difference. Cambridge Service Alliance, University of Cambridge, Cambridge*

106 *Zhang, W., & Banerji, S. (2017). Challenges of servitization: A systematic literature review. Industrial Marketing Management, 65, 217-227*

107 *Baines, T., & W. Lightfoot, H. (2013). Servitization of the manufacturing firm: Exploring the operations practices and technologies that deliver advanced services. International Journal of Operations & Production Management, 34(1), 2-35*

108 *Gebauer, H., Fleisch, E., Friedli, T. (2005). Overcoming the Service Paradox in Manufacturing Companies. European Management Journal, 23(1):14–26*

References

109 https://www.visualcapitalist.com/wp-content/uploads/2014/09/born-in-2010-how-much-metals-and-energy-is-left.png

110 https://www.eea.europa.eu/ims/waste-generation-and-decoupling-in-europe

111 https://ourworldindata.org/greenhouse-gas-emissions#annual-greenhouse-gas-emissions-how-much-do-we-emit-each-year

112 https://www.un.org/en/global-issues/population

113 (Ellen MacArthur Foundation. 2015. Towards a Circular Economy: Business Rationale for an Accelerated Transition. Ellen MacArthur Foundation)

114 Ibid.

115 (Acerbi, Federica, and Marco Taisch. 2020 "A Literature Review on Circular Economy Adoption in the Manufacturing Sector." Journal of Cleaner Production, July. Elsevier, 123086. doi:10.1016/j.jclepro.2020.123086)

116 (Ellen MacArthur Foundation. 2015. Towards a Circular Economy: Business Rationale for an Accelerated Transition. Ellen MacArthur Foundation)

117 https://www.ft.com/content/6cad1883-f87a-471d-9688-c1a3c5a0b7dc

118 ABB, https://global.abb/group/en

119 PulPac, https://www.pulpac.com/

120 Fairphone, https://www.fairphone.com/en/

121 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan_en

122 European Environment Agency, 2023 (https://www.eea.europa.eu/ims/circular-material-use-rate-in-europe)

123 https://circulareconomynetwork.it/2023/09/05/riciclo-imballaggi-conai/

124 https://www.ansa.it/ansa2030/notizie/finanza_impresa/2023/08/24/aziende-investire-in-economia-circolare-ripaga_10330f60-5be7-4896-a241-d8b14fe3b0a7.html

125 https://ec.europa.eu/research-and-innovation/en/projects/success-stories/all/extracting-rare-earth-elements-fertiliser-production

126 https://ec.europa.eu/research-and-innovation/en/projects/success-stories/all/bringing-circular-economy-practices-glass-and-carbon-fibre-composites

127 https://www.oecd-ilibrary.org/deliver/5d33734d-en.pdf?itemId=%2Fcontent%2Fpaper%2F5d33734d-en&mimeType=pdf

128 Teece, D. J. (2010). Business models, business strategy and innovation. Long range planning, 43(2-3), 172-194

129 Osterwalder, A., & Pigneur, Y. (2010). Business model generation: a handbook for visionaries, game changers, and challengers (Vol. 1). John Wiley & Sons.

130 Marcon, Érico, Marie Anne Le Dain, and Alejandro G. Frank. 2022. "Designing Business Models for Industry 4.0 Technologies Provision: Changes in Business Dimensions through Digital Transformation." Technological Forecasting and Social Change, 185).

131 Teece, D. J. (2010). Business models, business strategy and innovation. Long range planning, 43(2-3), 172-194.

132 https://www.ey.com/en_br/advanced-manufacturing/is-your-digital-strategy-fit-for-the-manufacturing-future

133 Gartner. 2023. "2023 CIO Agenda: 4 Actions to Ensure Your Tech Investments Pay Digital Dividends." Gartner.

134 https://global.abb/topic/ability/en and https://new.abb.com/service/motion

135 https://investor.gm.com/news-releases/news-release-details/general-motors-expands-digital-commerce-launch-online-parts/

136 Müller, J., & Buliga, O. (2019). Archetypes for data-driven business models for manufacturing companies in Industry 4.0. Proceedings of the International Conference on Information Systems (ICIS), Munich.

137 https://www.siemens.com/global/en/company/digital-transformation/xcelerator.html

138 https://www.kaeser.com/int-en/solutions/operator-models

139 https://global.hitachi-solutions.com/blog/achieve-outcome-based-service-model/

140 https://www2.deloitte.com/content/dam/Deloitte/de/Documents/industry-operations/Deloitte-Digital-Maturity-Index-Survey-2023.pdf

141 Favoretto, C., Mendes, G. H. D. S., Filho, M. G., Gouvea de Oliveira, M., & Ganga, G. M. D. (2022). Digital transformation of business model in manufacturing companies: challenges and research agenda. Journal of Business & Industrial Marketing, 37(4), 748-767.

142 Gartner. 2023. "2023 CIO Agenda: 4 Actions to Ensure Your Tech Investments Pay Digital Dividends." Gartner.

143 Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. Technological forecasting and social change, 132, 2-17.

144 Witschel, D., Müller, J. M., & Voigt, K. I. (2023). What Takes the Wind out of Their Sails? A Micro-Foundational Perspective of Challenges for Building Dynamic Capabilities Towards Digital Business Model Innovation. Schmalenbach Journal of Business Research, 1-44.

145 https://www.applicoinc.com/blog/ge-digital-failed/

146 Witschel, D., Müller, J. M., & Voigt, K. I. (2023). What Takes the Wind out of Their Sails? A Micro-Foundational Perspective of Challenges for Building Dynamic Capabilities Towards Digital Business Model Innovation. Schmalenbach Journal of Business Research, 1-44.

147 Voigt, K. I., & Müller, J. M. (2021). Digital business models in industrial ecosystems. Springer International Publishing.

148 Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. Technological forecasting and social change, 132, 2-17.

149 Kaiser, C., Stocker, A., Viscusi, G., Fellmann, M., & Richter, A. (2021). Conceptualising value creation in data-driven services: The case of vehicle data. International Journal of Information Management, 59, 102335.

150 Wixom, B. H., & Ross, J. W. (2017). How to Monetize Your Data. MIT Sloan Management Review. https://sloanreview.mit.edu/article/how-to-monetize-your-data/

151 Ulaga, W., & Reinartz, W. J. (2011). Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully. Journal of Marketing, 75(6), 5–23. https://doi.org/10.1509/jmkg.75.6.5

152 Rowley, J. (2007). The wisdom hierarchy: Representations of the DIKW hierarchy. Journal of Information Science, 33(2), 163–180.

153 Harvard Business Review Analytics Survey. (2022). Transforming Data into Business Value through Analytics and AI. Harvard Business Review. https://hbr.org/sponsored/2023/03/transforming-data-into-business-value-through-analytics-and-ai?autocomplete=true

154 https://www.reuters.com/technology/japan-leaning-toward-softer-ai-rules-than-eu-source-2023-07-03/

155 https://www.insideglobaltech.com/2020/01/14/ai-update-white-house-issues-10-principles-for-artificial-intelligence-regulation/

156 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0206, https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/698792/EPRS_BRI%282021%29698792_EN.pdf

157 https://www.appliedai.de/en/hub-en/ai-act-impact-survey

158 https://datainnovation.org/2021/07/ai-act-would-cost-the-eu-economy-e31-billion-over-5-years-and-reduce-ai-investments-by-almost-20-percent-new-report-finds/

159 https://www.appliedai.de/en/hub-en/ai-act-risk-classification-of-ai-systems-from-a-practical-perspective

160 https://appliedaiinitiative.notion.site/Risk-Classification-Database-2b58830bb7f54c9d8c869d37bdb27709

161 Noah Gift, Alfredo Deza - Practical MLOps_ Operationalizing Machine Learning Models-O'Reilly Media (2021)

162 A. Guazzelli, M. Zeller, W. Chen, and G. Williams. PMML: An Open Standard for Sharing Models. The R Journal, Volume 1/1, May 2009. http://journal.r-project.org/2009-1/RJournal_2009-1_Guazzelli+et+al.pdf

163 https://www.khronos.org/nnef

164 https://onnx.ai/

165 Elmaraghy, H. A. et Elmaraghy, W. H. (2012) 'Enabling Manufacturing Competitiveness and Economic Sustainability', Proceedings of the 5th International Conference on Changeable, Agile, Reconfigurable and Virtual Production (CARV 2013).

166 Koren, Yoram, et al. "Reconfigurable manufacturing systems." CIRP annals 48.2 (1999): 527-540.

167 Mehrabi, Mostafa G., A. Galip Ulsoy, and Yoram Koren. "Reconfigurable manufacturing systems: Key to future manufacturing." Journal of Intelligent manufacturing 11 (2000): 403-419.

168 Koren, Yoram. The global manufacturing revolution: product-process-business integration and reconfigurable systems. Vol. 80. John Wiley & Sons, 2010.

169 Andersen, A-L., Andersen, R., Napoleone, A., Brunø, T. D., Kjeldgaard, S., Nielsen, K., Sorensen, D. G. H., Raza, M., Bilberg, A., Rösiö, C., Boldt, S., & Skärin, FI. (2023). Paving the way for changeable and reconfigurable production: Fundamental principles, development method & examples. (1 udg.) REKON Press.

References

170 *Gunasekaran, A., Y. Yusuf, E. O. Adeleye, Papadopoulos, T. (2018) 'Agile Manufacturing Practices: The Role of Big Data and Business Analytics with Multiple Case Studies', International Journal of Production Research, 56(1-2), 385–397.*

171 *Brandl, F.J., Roider, N., Hehl, M., Reinhart, G. (2021) 'Selecting practices in complex technical planning projects: A pathway for tailoring agile project management into the manufacturing industry', CIRP Journal of Manufacturing Science and Technology, 33, 293-305.*

172 *Medini, K. (2023) 'A framework for agility improvement projects in the post mass customisation era', International Journal of Production Research, 61(20), pp. 7105-7121.*

173 *Duguay, C. R., S. Landry, and F. Pasin. (1997) 'From Mass Production to Flexible/ Agile Production." International Journal of Operations & Production Management, 17(12), 1183–1195.*

174 *Bottani, E. (2010) 'Profile and Enablers of Agile Companies: An Empirical Investigation', International Journal of Production Economics, 125, pp. 251–261.*

175 *Nakka, K., Dasari, R. (2021) 'Agile ecosystem: how to you get it right', Independently Published, 225p*

176 *Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., ... & Rockström, J. (2023). Earth beyond six of nine planetary boundaries. Science Advances, 9(37), eadh2458.*

177 *Pardo-Jaramillo, S., Muñoz-Villamizar, A., Osuna, I., Roncancio, R. (2020) 'Mapping research on customer centricity and sustainable organizations', Sustainability, 12(19), 7908.*

178 *Hänsch, A., Hora, M., Fontana, A., Hankammer, S., Canetta, L., & Gomez, S. (2018). A preparatory approach to environmental assessment for sustainable mass customization. In Customization 4.0: Proceedings of the 9th World Mass Customization & Personalization Conference (MCPC 2017), Aachen, Germany, November 20th-21st, 2017 (pp. 315-337). Springer International Publishing.*

179 *Hankammer, S., Kleer, R., & Piller, F. T. (2021). Sustainability nudges in the context of customer co-design for consumer electronics. Journal of Business Economics, 91(6), 897-933.*

180 *Hankammer, S., Jiang, R., Kleer, R., & Schymanietz, M. (2018). Are modular and customizable smartphones the future, or doomed to fail? A case study on the introduction of sustainable consumer electronics. CIRP Journal of Manufacturing Science and Technology, 23, 146-155.*

181 *Hora, M., Hankammer, S., Canetta, L., Sel, S. K., Gomez, S., & Gahrens, S. (2016). Designing business models for sustainable mass customization: a framework proposal. International Journal of Industrial Engineering and Management, 7(4), 143.*

182 *T. Baines and H. Lightfoot, Made to Serve: How manufacturers can compete through servitization and product–service systems. John Wiley & Sons, Ltd, 2013*

183 *A. A. Neff, F. Hamel, T. Ph. Herz, F. Uebernickel, W. Brenner, and J. Vom Brocke, "Developing a maturity model for service systems in heavy equipment manufacturing enterprises," Inf. Manage., vol. 51, no. 7, pp. 895–911, Nov. 2014, doi: 10.1016/j.im.2014.05.001*

184 *D. Heinz, C. Benz, R. Silbernagel, B. Molins, G. Satzger, and G. Lanza, "A Maturity Model for Smart Product-Service Systems," Procedia CIRP, vol. 107, pp. 113–118, 2022, doi: 10.1016/j.procir.2022.04.019*

185 *Riina Antikainen et al., "Circular Business Models: Product-Service Systems on the Way to a Circular Economy," European Network of the Heads of Environment Protection Agencies (EPA Network) - Interest Group on Green and Circular Economy, 2021. [Online]. Available: https://epanet.eea.europa.eu/reports-letters/reports-and-letters/circular_business_models_interest-group-green-and-circular-economy.pdf*

186 *Ezio Manzini and Carlo Vezzoli, "Product-Service Systems and Sustainability: Opportunities for sustainable solutions," United Nations Environment Programme (UNEP), 2002*

187 *M. A. Khan and T. Wuest, "Upgradable Product-Service Systems: Implications for Business Model Components," Procedia CIRP, vol. 80, pp. 768–773, 2019, doi: 2674, Dec. 2022, doi: 10.3390/pr10122674*

188 *Ezio Manzini and Carlo Vezzoli, "Product-Service Systems and Sustainability: Opportunities for sustainable solutions," United Nations Environment Programme (UNEP), 2002*

189 *P. Zheng, T.-J. Lin, C.-H. Chen, and X. Xu, "A systematic design approach for service innovation of smart product-service systems," J. Clean. Prod., vol. 201, pp. 657–667, Nov. 2018, doi: 10.1016/j.jclepro.2018.08*

190 *Lewandowski 2016 – "Designing the Business Models for Circular Economy—Towards the Conceptual Framework", Sustainability, 8, 43; doi:10.3390/su8010043*

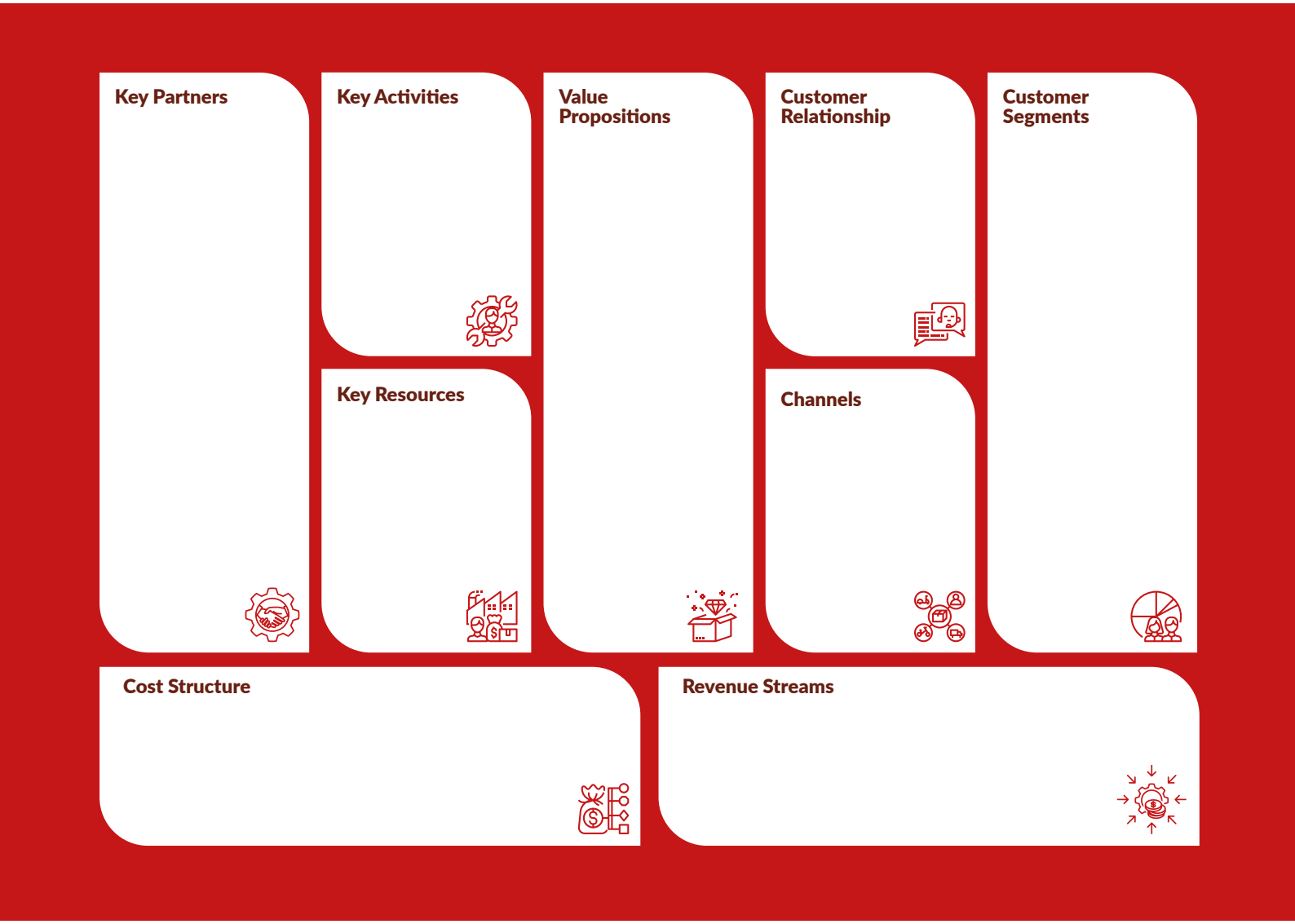
191 *Chari, A., Niedenzu, D., Despeisse, M., Machado, C. G., Azevedo, J. D., Boavida-Dias, R., & Johansson, B. (2022). Dynamic capabilities for circular manufacturing supply chains—Exploring the role of Industry 4.0 and resilience. Business Strategy and the Environment, 31(5), 2500–2517. https://doi.org/10.1002/bse.3040*

192 *Ibid. Chari, A., Niedenzu, D., Despeisse, M., Machado, C. G., Azevedo, J. D., Boavida-Dias, R., & Johansson, B. (2022). Dynamic capabilities for circular manufacturing supply chains—Exploring the role of Industry 4.0 and resilience. Business Strategy and the Environment, 31(5), 2500–2517. https://doi.org/10.1002/bse.3040*

193 *https://extension.harvard.edu/blog/introducing-handprints-a-net-positive-approach-to-sustainability/*

Annexes

BUSINESS MODEL CANVAS



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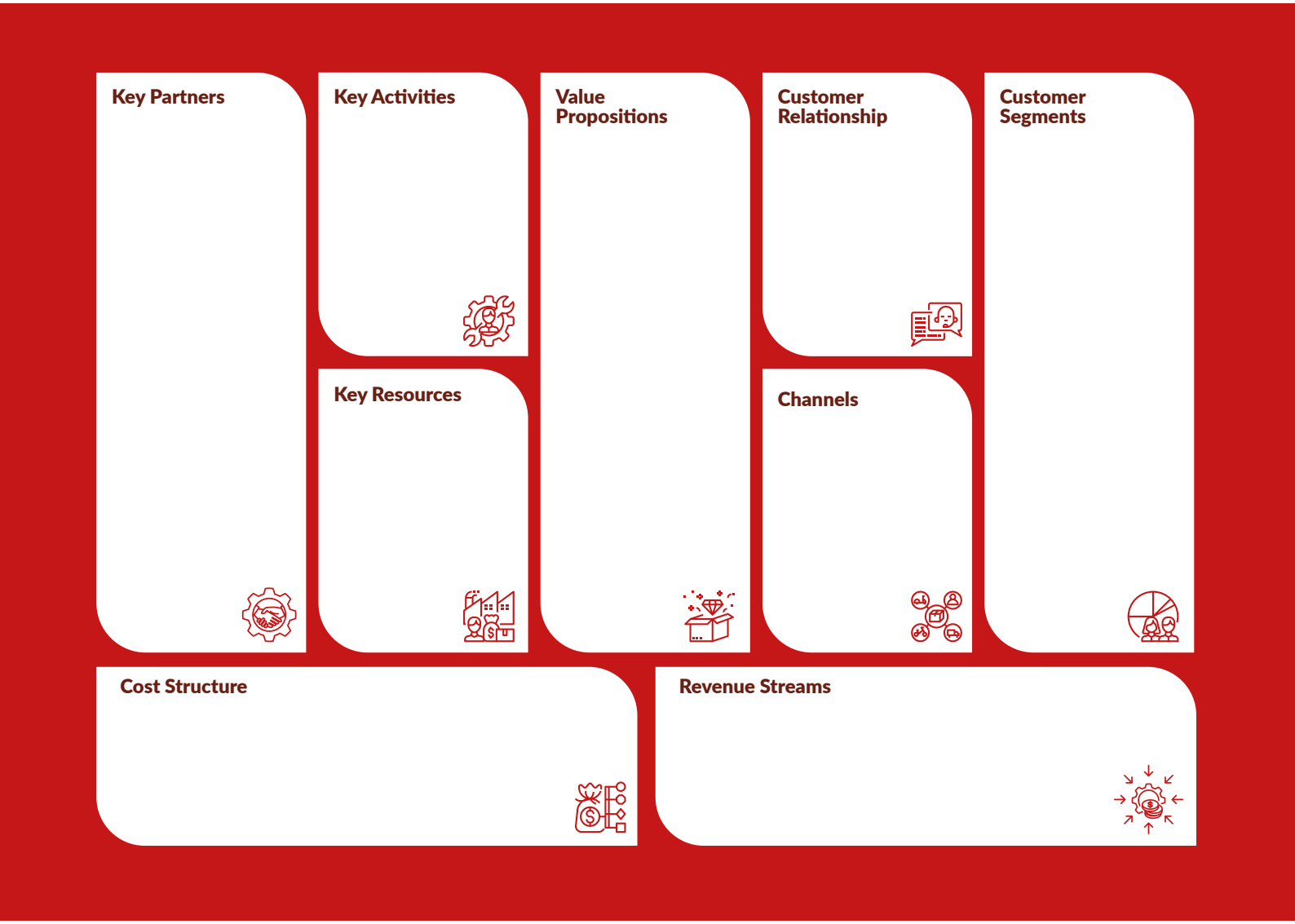

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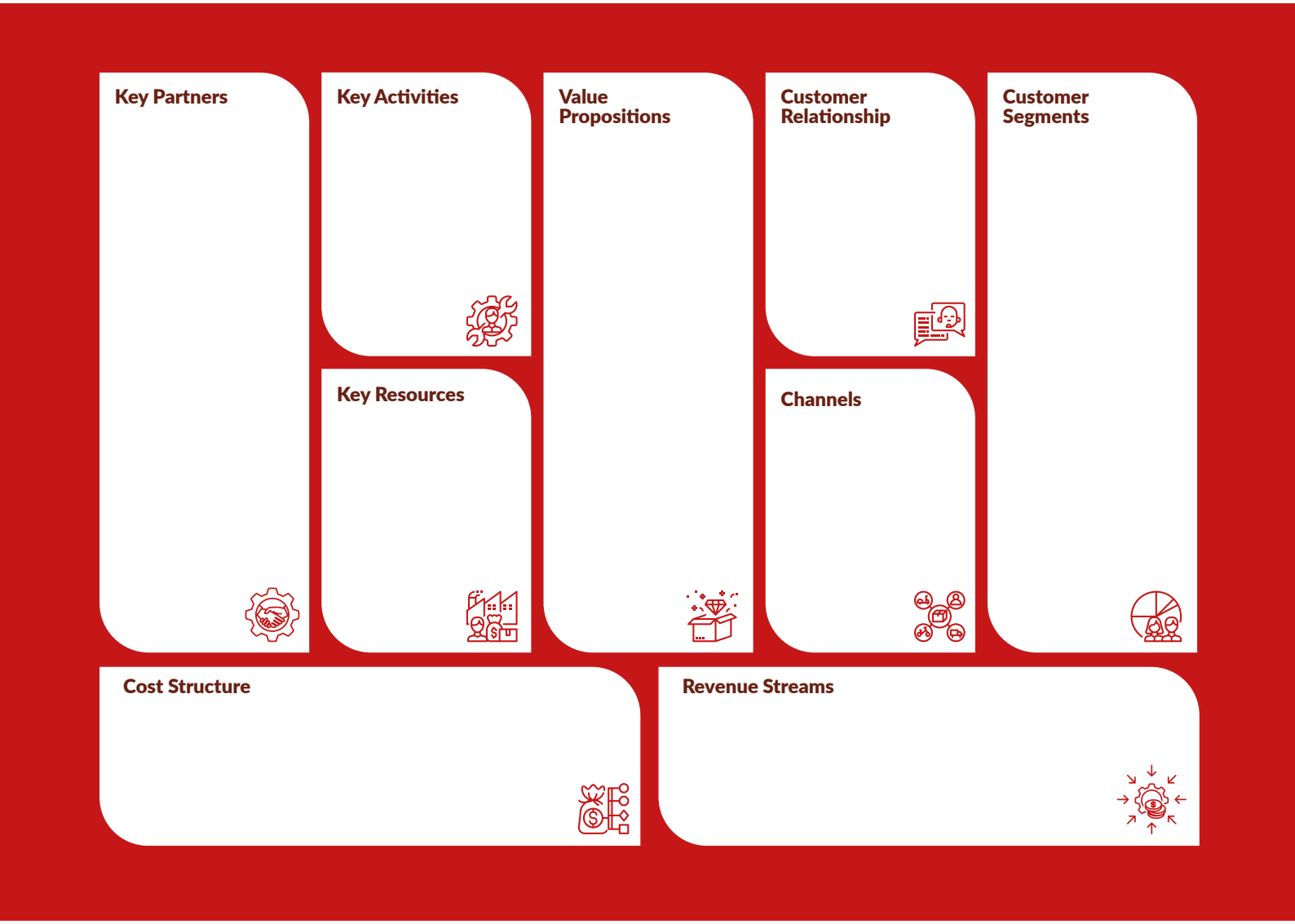

The World Manufacturing Foundation

Vision

"We strive to enhance manufacturing's role as a dynamic and positive driver for economic, social, and environmental growth and sustainability".

Mission

The World Manufacturing Foundation is an open platform spreading industrial culture worldwide. We promote innovation and development in the manufacturing sector, with the fundamental goal of improving societal wellbeing and inclusive growth in all nations through dialogue and cooperation among the manufacturing sector's key players.

We will pursue our goals by:

- supporting and shaping local and international industrial agendas
- providing a framework through which companies, governments, academic institutions and social organisations can interact or collaborate, acting as a catalyst for finding innovative solutions to major global challenges
- creating and disseminating knowledge in both policy and technology through local and international meetings and publications.

WORLD MANUFACTURING FOUNDATION

Spreading Industrial Culture Worldwide

The World Manufacturing Foundation was formally established in May 2018 in Milan, Italy, as a platform to promote industrial culture and sustainable manufacturing practices worldwide. This undertaking was spearheaded by three founding partners: Confindustria Lombardia, IMS International, and Politecnico di Milano. The Foundation aims to spread industrial culture by expanding knowledge, promoting innovation, and fostering cooperation in the manufacturing sector.

The Foundation capitalises on its wealth of experience in hosting annual manufacturing events to discuss the most pressing challenges confronting the sector. In fact, long before the Foundation was formally established, the annual World Manufacturing Forum has been staged since 2011. The very first edition was held in Cernobbio in Lombardy and started as an important platform for global industry leaders and other stakeholders to exchange opinions on different issues related to manufacturing. The Forum started as a project funded by the European Commission, which has also supported its succeeding editions.

The World Manufacturing Foundation also has the support of important organisations. The Foundation was kick-started with the support of Regione Lombardia, which has also provided financial support in the last few years. In 2018, the World Manufacturing Foundation also signed a joint declaration with the United Nations Industrial Development Organization (UNIDO) to promote a common global agenda on technological innovation and inclusive and sustainable industrialisation, and to advance the 2030 Agenda for Sustainable Development.

The business model which defines the Foundation is that of the Triple Helix. Its competitiveness is empowered through an intersectoral collaboration engaging industry, academia, and government. This is evident in the nature of its founding and key partners and a large community of institutional partners from all over the world, which support the Foundation's initiatives.

World Manufacturing Foundation Members

CONFINDUSTRIA Lombardia

POLITECNICO MILANO 1863

Thanks to

European Commission

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Regione Lombardia

2023 KEY RECOMMENDATIONS BY THE WORLD MANUFACTURING FOUNDATION

1. EMBRACE A CUSTOMER-CENTRIC INNOVATION APPROACH TO FOSTER LOYALTY AND DRIVE GROWTH
2. CREATE SUSTAINABLE VALUE PROPOSITIONS BASED ON THE TRIPLE BOTTOM LINE FOR A COMPETITIVE EDGE
3. AIM FOR MASS-CUSTOMISED AND PERSONALISED VALUE PROPOSITIONS TO CREATE HIGHER BENEFITS FOR CUSTOMERS
4. DEVELOP NEW SALES CHANNELS FOR HYBRID REVENUE STREAMS
5. FOSTER TIGHTER BONDS BY CREATING IMPROVED CUSTOMER RELATIONSHIPS
6. UNLOCK VALUE POTENTIAL BY HARNESSING AI AND DATA ANALYTICS FOR NEW REVENUE STREAMS
7. BALANCE KEY RESOURCES TO AVOID THEIR OVER - AND UNDERESTIMATION FOR SUSTAINABLE OPERATIONS
8. PRIORITISE LOCALISED MANUFACTURING AND STRENGTHEN CORE COMPETENCIES FOR MARKET AGILITY AND SUSTAINABILITY
9. EXPAND PARTNERSHIPS BEYOND TODAY'S VALUE CHAINS' TRADITIONAL BOUNDARIES TO PREPARE FOR NEW CHALLENGES AND RISKS
10. OVERCOME INVESTMENT BARRIERS TO ESTABLISH TRUSTING RELATIONSHIPS TO UNLEASH CONTINUOUS CASH FLOW FROM ASSETS

World Manufacturing Foundation
Global Headquarters:
Via Pantano, 9 - 20122 Milano, Italy

worldmanufacturing.org