VTT Technical Research Centre of Finland

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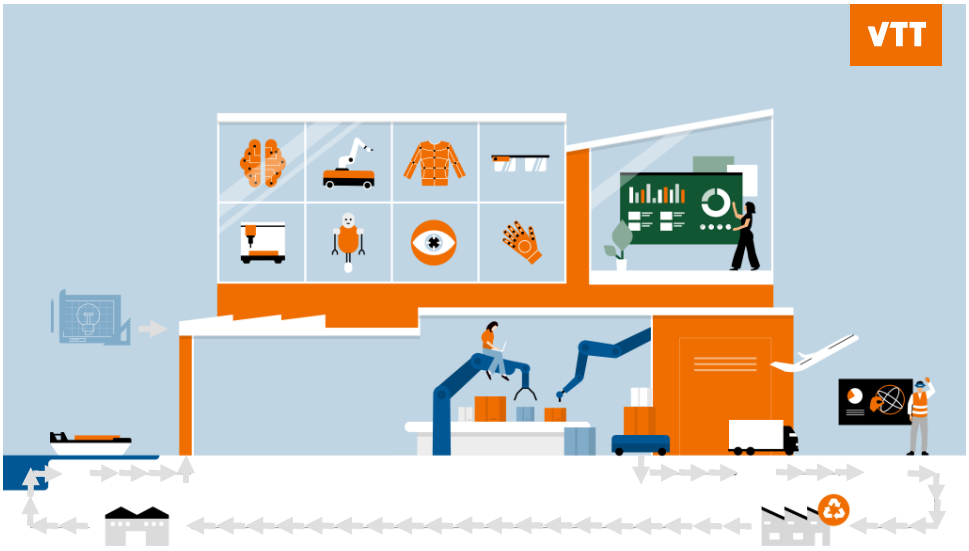
Published: 30/11/2020

Document Version
Publisher's final version



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Final

30 November 2020

1. Introduction

Digitalisation is progressing in every domain, including the manufacturing industries. Digitising, digitalisation and digital transformation are concepts that are sometimes mixed or intentionally broaden or constricted. For us digitising is the way to provide a digital presentation (model) of an entity i.e. converting information from a physical format into a digital one. Digitalisation means the implementation of processes or services via information and communication technologies (ICT). Digital transformation is the way to digitalise your product, services or processes; i.e. how to proceed with digitalisation.

In Finland, there are examples of ICT forerunners on manufacturing sector. For example, Cargotec already has over 250 implemented robot process automation applications. The first industrial 5G, edge-computing and AI-based machine-vision system can detect errors and guide workers online at ABB[1]. However, there are some smaller forerunners, too. For example, Mantsinen[2] has implemented intelligent maintenance service based on an Internet of Things (IoT) solution that feeds 50 different bus signals into the cloud about every second. This service is piloted with material handling machinery in a harbour in the UK.

This leaflet focusses on Finnish manufacturing small- and medium-sized enterprises (SMEs) and clarifies their digitalisation status, challenges and potential technologies. Some supportive actions are proposed. VTT's role and means to support those SMEs will be considered in more detail soon.

Juhani Heilala, Heli Helaakoski, Risto Kuivanen, Jukka Kääriäinen, Leila Saari

[1] https://new.abb.com/news/detail/25464/worlds-first-industrial-application-utilizing-5g-and-ai-adopted-at-abb-drives-factory-in-helsinki

[2] https://www.tekniikkatalous.fi/uutiset/data-lisaa-tuskaa-tulvii-ovista-ja-ikkunoista-niin-paljon-etta-tieto-hukkuu-jo-alle-hurjimmatkin-visiot-nayttavat-toteutuvan/ca8e41a4-c0c8-3787-b2d5-d6aa5a4d51a2

2. Digital transformation

In recent years, the digitalisation of manufacturing has emerged as one of the most important themes in the manufacturing and innovation policies and R&D portfolios of major economies. In particular, the convergence of digital technologies such as cyber-physical systems, cloud computing, big data, artificial intelligence, machine learning and the internet-of-things, among others, offers the potential to more effectively connect and integrate manufacturing systems.

These advanced technologies are enabling more rapid development of efficient new products and logistics. Such technologies also allow manufacturing industries to better meet customer and user demands such as greater personalisation, higher safety levels and improved energy and resource efficiency. The digital transformation wave in manufacturing is driven by the following major developments[3]: technology trends, customer-demand trends, industry pressures and drivers and policy and regulatory developments (Figure 1).

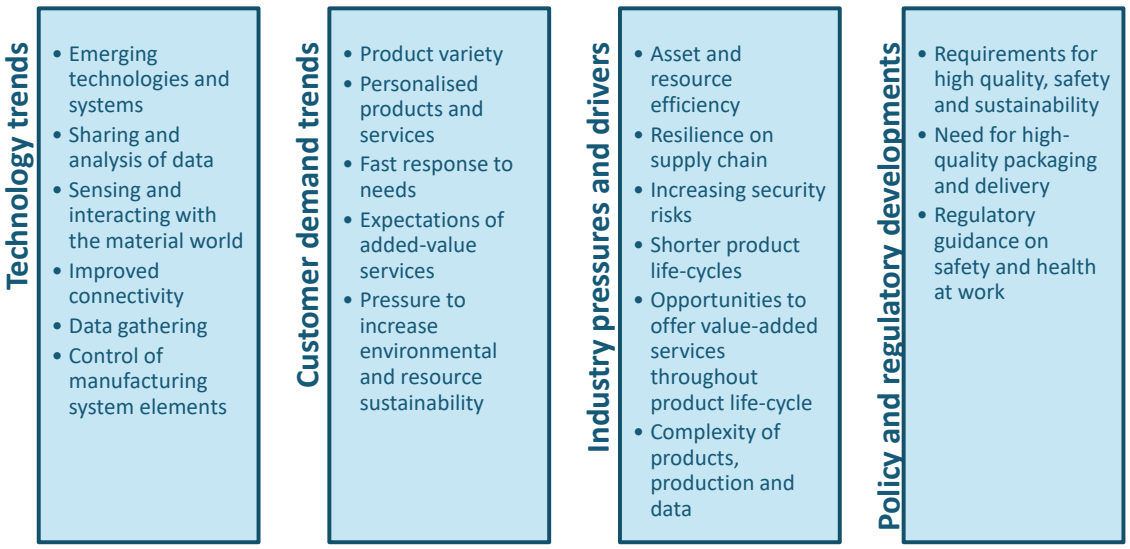

Figure 1. Four trends driving digitalisation.

Digitalisation builds on a wide range of new technologies to create value through seamlessly generating, analysing and communicating data. The German initiative for renewing the manufacturing industry, Industry 4.0, refers to the transformation of industry through the intelligent networking of connected machines and processes with the help of ICT.

Digitalisation has been compared to the industrial revolution[4]. Digitalisation is referred to as a more fundamental change than just digitising existing processes or work products. Whereas 'digitisation' refers to the action or process of digitising analogue data into digital form, 'digitalisation', or digital transformation, means changes in ways of working, roles and business offerings caused by adopting digital technologies in an organisation or the operation environment of the organisation[5]. Digitalisation can bring new business opportunities and models, change the roles of operators in a value chain and even end existing businesses[6].

The level of digitalisation refers to companies' ability to exploit digitalisation means in manufacturing processes or supporting activities such as logistics. In Finland, manufacturing SMEs are on different levels of digitalisation. Generally, Finns have strong

[3] https://capacitydevelopment.unido.org/wp-content/uploads/2017/06/emerging_trends_global_manufacturing.pdf

[4] http://www.economist.com/node/21553017

[5] https://cris.vtt.fi/en/publications/tackling-the-digitalisation-challenge-how-to-benefit-from-digital

[6] http://www.vtt.fi/inf/pdf/technology/2016/T278.pdf

digitalisation skills, but the overall exploitation throughout the manufacturing processes could be improved. There are highly digitalised companies but there are also manufacturing SMEs lacking digitalisation skills, means and tools. The effective use of digital solutions would raise SMEs' competitiveness and. Seamless information exchange and communication are the prerequisites for modern business processes by bringing effectiveness and reliability.

We need to improve the exploitation of digitalisation in the Finnish manufacturing industry to stay competitive. The manufacturing industry is willing to proceed towards Industry 4.0 and even beyond. Digitalisation is developing from manual data management of single companies towards intelligent data processing and analytics in partner networks enriched by the capabilities of artificial intelligence (Figure 2). The long-term vision of manufacturing is that digitalisation is supporting all manufacturing processes and collaboration with partner networks.

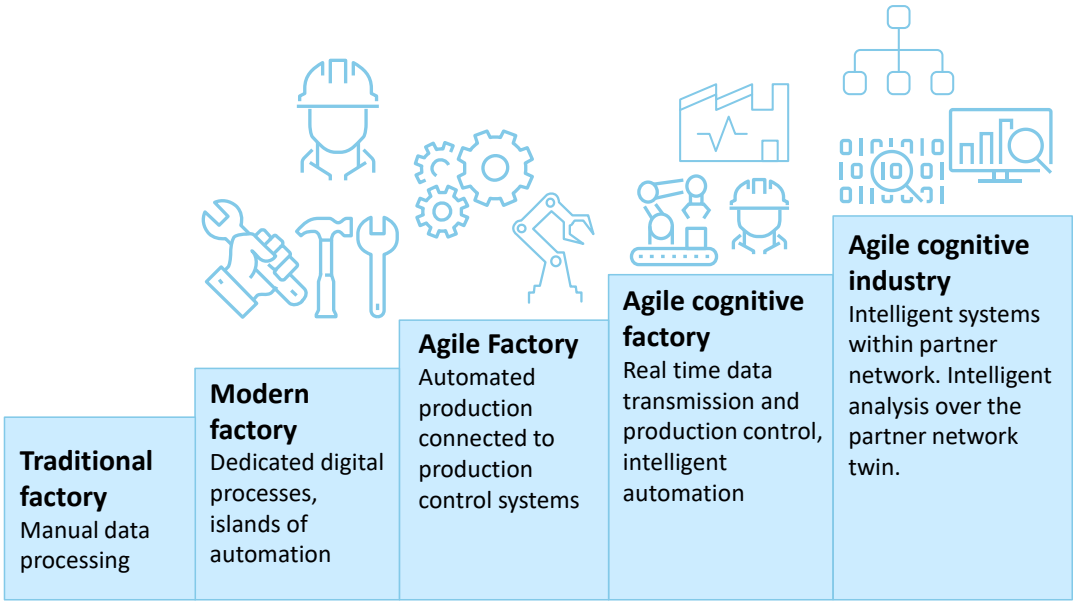

Figure 2. The digitalisation stairs for the manufacturing industry.

3. Digitalisation in Finnish manufacturing companies

In the EU, Finland has a good position for digitalisation. Digital Economy and Society Index (DESI) statistics[7] from year 2020 show that many areas are doing well and that industry, especially, has improved its competitive edge in recent years. The improvements are strongly dependent on the sizes of companies, and one part of the SME companies is still only beginning. Figure 3 shows the ranking of Member States on the DESI in 2020 based on 2019 data. Finland, Sweden, Denmark and the Netherlands have the most advanced digital economies in the EU; the same countries have remained in the top position in recent years.

According to Statistics Finland[8], the digitalisation of industry has generally progressed at an average pace with other business activities. For small companies with less than 100 employees, the pace has been slower than for other companies. In 2019, 79% used cloud services in companies with at least 10 employees. The largest shares of these were via email (69%), file storage (57%) and office software (55%). Seventeen percent of companies applied for computing power from services.

[7] https://ec.europa.eu/digital-single-market/en/desi

[8] https://www.stat.fi/til/inn/2016/inn_2016_2018-04-12_kat_009_fi.html

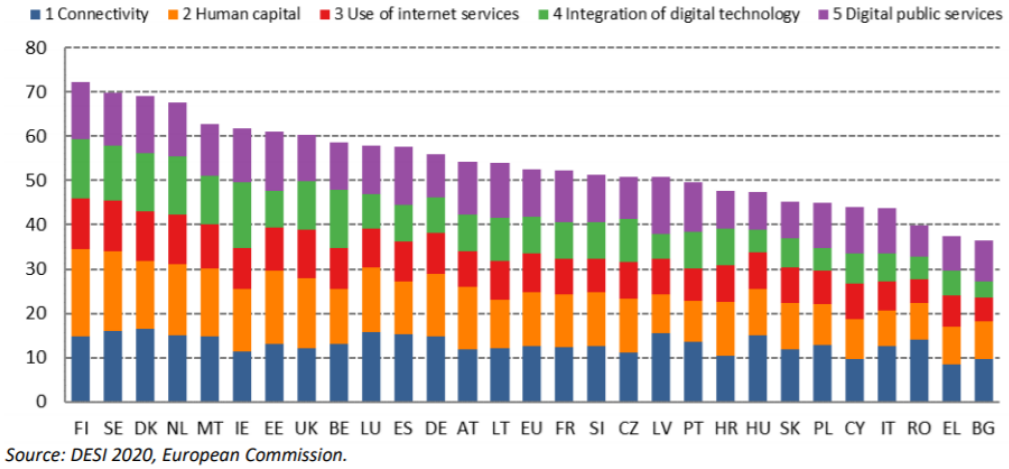

Figure 3. Digital Economy and Society Index in 2020.

Enterprise Resource Planning (ERP) software is used by 62% of companies, which is clearly above the average (43%). The differences between large and small companies are significant (29%–84%). The prevalence of ERP systems has clearly increased since 2017. Customer Relationship Management (CRM) software related to customer data management is used in the industry by 40% of companies, which is also the average for the business field. Here, too, the effect of company size is considerable, ranging from 32% to 70%. Twenty-nine percent of companies have IT professionals among the industry's own staff, which is close to the average for all sectors (26%).

The overall uptake of IT has great potential for increasing industrial productivity, but it is still at a very low level in many respects. The big problem is the lack of IT professionals in small businesses and the low level of general IT skills. However, the digitalisation support service business is becoming more common, and small businesses also have access to IT support at a reasonable cost around the clock.

The number of industrial robots per 10,000 employees is a sign of the degree of automation in industry. In particular, the use of industrial robots has been recorded for several decades. As technical devices, robots eventually come to the end of their service life and new applications always come along.

Statistics concerning the amount of industrial robots[9] in the manufacturing industry show that Finland is globally advanced. In 2004, Finland was even at the top. However, Finland's investment has weakened considerably in recent years and in year 2017 Finland's ranking was 17th (Figure 4)[10]. At the same time, the total global sales of industrial robots have increased almost sevenfold from 2009 to 2019, amounting to approximately 381,000 units worldwide in 2019. South Korea and Singapore’s robots installation numbers were about five to six times bigger than Finland’s.

The number of industrial robots (Figure 4) is naturally affected by the structure of the industry. Of the industries, the automotive industry uses robots the most. The use of robots is challenging in small series production due to pay back times. In Finland there are few car factories but many small machinery workshops making short series. Still, arc-welding applications have been well-used by the Finnish industry, unlike in the rest of the world. Recent developments in digital twin modelling, for example, have brought relief to the programming of industrial robots. The introduction of applications in very small series has become profitable. The prices of industrial robots have decreased and they offer a real alternative for even SMEs to increase their productivity.

[9] https://roboyhd.fi/

[10] https://ifr.org/downloads/press2018/WR_Presentation_Industry_and_Service_Robots_rev_5_12_18.pdf

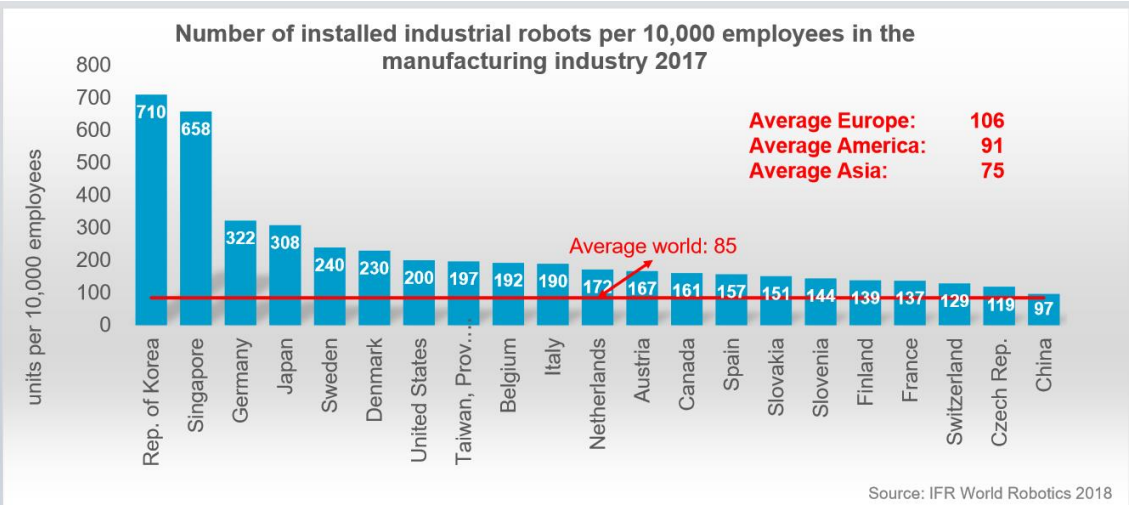

Figure 4. Industrial robot installations per 10,000 employees in 2017.

COVID-19 pandemic and related disruptive circumstances have set severe challenges for the manufacturing industry. In Finland, Business Finland has supported over 30,000 companies, in which the share of industrial companies is around 11%[11]. Unfortunately, the rules of support have excluded exporting SMEs, which are relevant for the recovery of the Finnish industry and economy. The technology industries of Finland (Teknologiateollisuus) follow monthly the pulse of their member companies[12]. Currently, the estimates of the on-going transition are very uncertain.

4. Digitalisation capabilities and challenges in manufacturing SMEs

The Finnish industry is undergoing a polarisation of digitalisation, with pioneers at one end and SMEs at the other. In 2018, the World Economic Forum reported on the 'Readiness for the Future of Production[13]' in 100 countries and economies. Nordic countries represent a group that displays a high level of readiness for the future of production, as all countries perform well across the drivers of production: i) technology and innovation, ii) human capital, iii) global trade and investments, iv) institutional framework, v) sustainable production, and vi) demand environment. These six drivers represent factors and conditions necessary to capitalize on emerging technologies and transform production systems. Finland is 8th among the leading countries.

The status of digitalisation has remained somewhat stable in Finland over the past few years. The share of enterprises doing electronic sales to other EU countries has remained stable, as well as their share of total turnover from e-commerce. On the other hand, the share of enterprises selling online, using two or more types of social media and buying cloud computing services of medium–high sophistication, has increased[14].

The Nordic Council's study[15] divides SME manufacturing companies into three categories regarding the level of digitalisation and automation: low, basic–moderate and advanced. On average, Nordic countries are at the same level, but the study also shows that only 40% of Finnish and Swedish companies are at a low level. Therefore, a large

[11] https://www.businessfinland.fi/en/whats-new/news/2020/business-finland-received-nearly-30000-applications-for-funding-for-business-development-in-distruptive-circumstances/#ee37e04c

[12] https://teknologiateollisuus.fi/fi/ajankohtaista/uutinen/nakymat-eivat-ole-kirkastuneet-teknologiateollisuudessa-pohjakosketus-vasta

[13] https://www.weforum.org/reports/readiness-for-the-future-of-production-report-2018

[14] https://www.weforum.org/whitepapers/the-next-economic-growth-engine-scaling-fourth-industrial-revolution-technologies-in-production

[15] http://norden.diva-portal.org/smash/get/diva2:876658/fulltext01.pdf

percentage of manufacturing SMEs are not utilising digital means in their daily business and are therefore diminishing their competitiveness and increasing the risk of losing their business. [16]

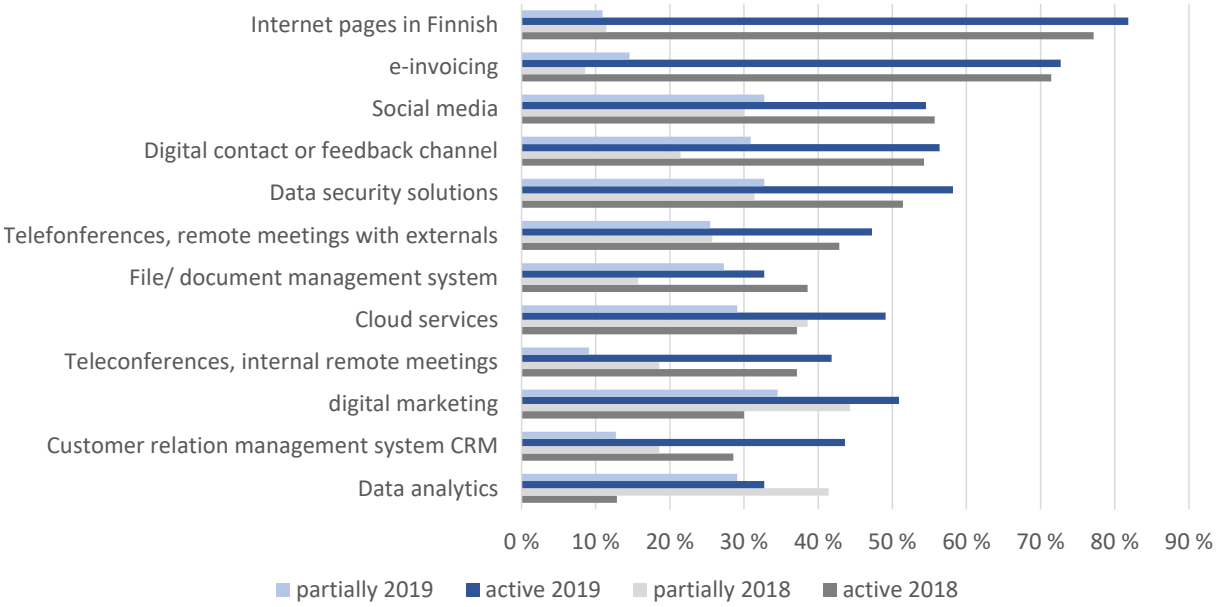

Figure 5. The most common digital solutions in 2018 (N=75) and 2019 (N=55).

In the digitalisation study[17], the most-exploited digital solutions were internet pages in Finnish, e-invoicing, social media and digital contact or feedback channel (Figure 5). The same survey also reveals that over 60% of companies estimate that the impact of digitalisation will continue to grow. Furthermore, the next digital solutions to be implemented will be AI applications, mobile applications, data analytics, CRM, big data, IoT, webshop, mobile payments and ERP.

Digital transformation provides new business possibilities but also sets challenges for manufacturing companies. Besides manufacturing skills, they also need to learn new capabilities. Now manufacturing SMEs are struggling with resource constraints and knowledge gaps that slow down their digitalisation efforts. The main challenges and barriers to overcome are limited understanding, insufficient resources and gaps in bringing digitalisation into practice (Figure 6).

Limited understanding

- Highly dependent on the passion and interest that the owner or **manager** has for technology.
- No **understanding** of the **opportunities** that digital technologies could bring to business.
- **Fear of vendor lock** and continuously rising periodic fees without promise of added value.

Insufficient resources

- No **time** to get acquainted with the possibilities of digitalization.
- The costs and **payback time** of the digitalization is unclear.
- Shortage of **skilled** people to either envision, implement or purchase digital solutions.

Gap in bringing into practice

- Difficulties to find a way to proceed and find suitable - simple and cost efficient enough - **tools to implement digital transformation in practice.**
- No competences to **split total delivery** into several implementation circles, proof-of-concepts and pilot experimentations.
- Difficulties to choose a good **solution provider**.

Figure 6. Typical challenges and pain points of SMEs to overcome.

[16] https://www.norden.org/en/publication/digitalisation-and-automation-nordic-manufacturing-sector

[17] https://cris.vtt.fi/en/publications/apuadigiin-digimuutos-suomalaisissa-pk-yrityksiss%C3%A4

On the other hand, SMEs are agile, as they can be flexible in implementing projects and carrying out rapid openings. SMEs are less formalized, less constrained, faster and even more flexible compared to large enterprises. Thus, SMEs generally can implement radical innovation, especially if they can capitalise on the guidance and support provided by publicly funded units (e.g. universities, research institutes, public authorities). As COVID-19 has been speeding up the adoption of digital tools and channels everywhere, SMEs have also made huge digitalisation progress during this exceptional time.

A recent survey[18], mainly looking at SMEs, has revealed that companies' future development activities will focus on new business models for entirely new opportunities and expanding or improving existing services or products using digital solutions.

Large companies have started to introduce new technologies related to Industry 4.0 in production, logistics and the value chain. The manufacturing SME companies will have to adapt to new Industry 4.0 standards and methods to remain competitive and linked to existing value chains and production networks. Original Equipment Manufacturers (OEMs) will expect manufacturing SMEs to be able to collaborate on digital design and engineering and to use digital manufacturing tools to optimise production. There is also a need for real-time manufacturing data sharing for value chain optimisation[19].

5. Ways to support manufacturing SMEs in digitalisation

Supporting industry in digitalisation is an important goal for authorities; it is the key element of competitiveness. Digitalisation has been supported with various development projects providing tools, methods, case examples, networks and indexes. This chapter provides an overview of digital maturity tools, national and international development efforts and ecosystems.

5.1 Maturity tools for assessing position in digitalisation

A maturity tool is useful when an organisation is willing to progress towards a goal but does not know how to proceed. An effective tool will give a common understanding of the necessary viewpoints, the current status and comparison to others. The tool will also help to find the potential development areas and initiate the discussion in the organisation. VTT has created three maturity web tools for three development goals (Figure 7). These self-assessment tools are available for non-commercial use in both Finnish and English.

DIGI maturity

To discover the maturity and potential development path of **digitalisation**

https://digimaturity.vtt.fi

AI maturity

To discover the maturity and potential development path of applying **artificial intelligence**

https://ai.digimaturity.vtt.fi

Manu Maturity

To discover the maturity and potential development path of being **beyond Industry 4.0**

https://manumaturity.vtt.fi/

Figure 7: Self-assessment tools for digitalisation, AI and Industry 4.0 maturity

[18] https://cris.vtt.fi/en/publications/apuadigiin-digimuutos-suomalaisissa-pk-yrityksiss%C3%A4

[19] https://www.nist.gov/blogs/manufacturing-innovation-blog/digital-manufacturing-small-manufacturers

First, the Digimaturity tool[20] assesses maturity and identifies potential development paths of digitalisation for an organisation. The AI maturity tool[21] helps companies proceed with AI exploitation and ManuMaturity[22] guides industry to reach beyond Industry 4.0.

In practice, these web tools are available for self-assessment. After registration, the user will answer questions simply by selecting from the prewritten response options. The immediate result graph (Figure 8) illustrates both the present state, the potential development needs and variation between other respondents. After the self-assessment, it is possible to have a results discussion, workshop or further development projects.

Figure 8. Immediate result graph; an example from DigiMaturity.

Several other maturity tools have been developed and published; for example, the Advanced Manufacturing Company Scan[23], Industrie 4.0-Readiness-Check[24], VDMA Readiness Model Survey 2015[25], the Organisational Maturity Model in Terms of Mass Customization[26], AI-Affected Autonomy Levels of Industrial Production[27], the Maturity Model for Digitalisation within the Manufacturing Industry's Supply Chain[28], the Maturity Model for Data-Driven Manufacturing[29], the Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises[30], the System Integration Maturity model[31] and many more.

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[20] https://digimaturity.vtt.fi http://www.vtt.fi/inf/pdf/technology/2017/T288.pdf

[21] https://ai.digimaturity.vtt.fi/ https://doi.org/10.32040/Whitepaper.2019.AIMaturity

[22] https://manumaturity.vtt.fi/

[23] https://www.surveymonkey.de/r/YSYDV9Y

[24] https://www.industrie40-readiness.de/?lang=en

[25] VDMA Industrie 4.0 Readiness Study

[26] https://link.springer.com/book/10.1007/978-3-030-25425-4

[27] https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/AI-in-Industrie4.0.html

[28] https://pdfs.semanticscholar.org/e62a/75a1c1aa3c69eb7738199f51a21ef8b4901f.pdf

[29] https://doi.org/10.1016/j.procir.2017.03.309

[30] https://doi.org/10.1016/j.procir.2016.07.040

[31] http://ieeexplore.ieee.org/document/7733413/

5.2 Regional development projects

The **ApuaDigiin** web service[32], developed in a regional development project, supports SMEs to systematically advance in digitalisation by analysing their current states of digitalisation and advance their digital transformation. The web service contains the digital transformation model for SMEs (Figure 9) tools and methods for improving digitalisation, digitalisation-related research and companies' digitalisation experiences (digitalisation stories). ApuaDigiin is a free web service for companies for studying and improving their digitalisation.

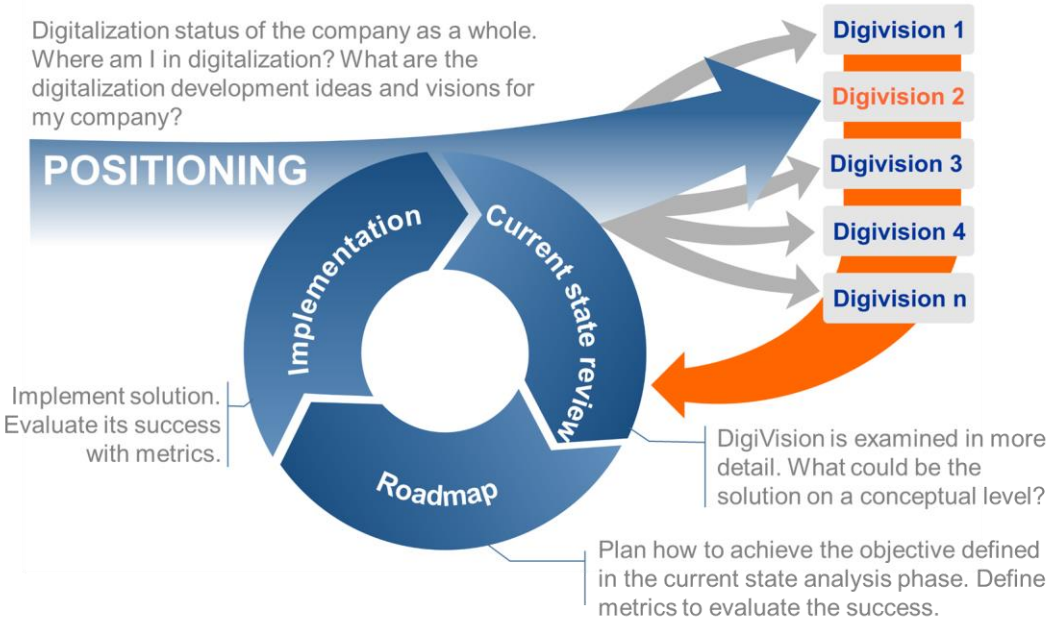

Figure 9. The tools and methods on the ApuaDigiin.fi web service guide SMEs to proceed with digitalisation based on the digital transformation model.

The **DigiTriangle** is an example of the tools available from the ApuaDigiin web service. The development ideas for digital transformation can be divided into three possible directions[33] according to their business goals: internal efficiency, exploitation of external opportunities or a more disruptive change.

The DigiGain (**DigiHyöty**[34]) project is funded by the European Social Fund/Häme ELY Centre, ending in August 2022. The project will provide information about the development needs of SMEs and the suitability of the current model of information technology implementation guidance for company development. As a result, digital technology and technology experts can better support the development activities of SMEs.

Finally, with the **UEF Digicenter**[35], the University of Eastern Finland promotes the application of digitalisation and modern artificial intelligence.

[32] https://www.apuadigiin.fi/

[33] https://cris.vtt.fi/en/publications/tackling-the-digitalisation-challenge-how-to-benefit-from-digital

[34] https://tieke.fi/hankkeet/digihyoty-digitalisaation-mahdollisuudet-hyotykayttoon-pk-yrityksissa

[35] https://www3.uef.fi/-/uusi-digikeskus-edistaa-digitalisaation-ja-modernin-tekoalyn-soveltamista-ita-suomessa

5.3 Ecosystems and solution provider indexes

The **DIMECC Intelligent Industry**[36] ecosystem focuses on refining digital data into functional physical products and services. The ecosystem acts as a digital innovation hub, helping SMEs with their digital transformations. Key services include, e.g., Finnish Industrial Internet Forum (FIIF)[37], DIMEC Demobooster, Demola and Machine Learning Academy.

VTT has created several industrial ecosystems to tackle the challenges of industry . To list a few: Research Alliance for Autonomous Systems (**RAAS**)[38], **SEED**[39] to connect IT and the forest industry, smart building platform **KEKO**[40] and **Reboot IoT Factory**[41].

SMACC, Smart Machines and Manufacturing Competence Centre[42], operates as a core of the Smart Manufacturing Digital Innovation Hub in Finland.

On the **ite wiki**[43] index site, you can search for suitable software companies, IT service providers, web and mobile developers, digitalisation experts and business development partners. The providers can publish their competences and references on the site with or without a fee.

5.4 Online training

DiKATA provides online courses[44] that are open to everyone and free of charge. Participants gain useful digital skills for work and leisure, whether they are beginners or experienced. Sample topics include how to use social media effectively, web publishing, how to use cloud services and how to manage information and security. Participants also learn important digital skills in networked working life, such as remote meeting practices and community working methods (Google and Microsoft Teams).

The **Google Digital Garage**[45] website provides a set of online courses in Finnish. For example, there are four courses in the Data and Technology section: Introduction to Coding, Introduction to Machine Learning and Improve Your Company's Network Security. Digital marketing offers eight courses. Studying those courses can help you grow your business or advance your career.

Elements of AI[46] is a series of free online courses trying to demystify AI. It encourages people to learn what AI is, what can (and cannot) be done with AI and how to start creating AI methods.

5.5 International efforts for digitalisation in manufacturing

Implemented use cases, success stories and experiments showing technology applications used for solving specific production problems and related business value

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[36] https://intelligentindustry.dimecc.com/

[37] https://fiif.fi/

[38] https://autonomous.fi/raas-research-alliance-to-support-innovations-in-the-automation-of-transport-and-logistics/

[39] https://seedecosystem.fi/

[40] https://kekoecosystem.com/

[41] https://rebootiotfactory.fi/

[42] https://www.smacc.fi/

[43] https://www.itewiki.fi/

[44] https://snellmankesayliopisto.fi/dikata/

[45] https://learndigital.withgoogle.com/digitalgarage-fi

[46] https://www.elementsofai.com/

are useful. The production problems can be across machining, assembly, maintenance, quality, supply chain, design, prototyping and engineering and beyond the factory's four walls. Some public sources are listed below.

European Advanced Manufacturing (**ADMA**) Support Centre helps SMEs assess the possibility of adopting both advanced manufacturing solutions as well as social innovation strategies thereby transforming their organization towards next-generation factories with more competitive, modern and sustainable production. ADMA[47] has developed a transformation methodology with tree steps: i) ADMA Scan, ii) ADMA Transformation plan, and iii) ADMA Implementation plan.

EFFRA (European Factories of the Future Research Association)[48] provides descriptions of pathways to digitalise manufacturing. These pathways are Autonomous Smart Factories, Hyperconnected Factories and Collaborative Product-Service Factories. The pathways are visible on the Structured Wiki Portal[49]. The European Commission Factory of the Future (FOF) projects, national or regional project results and demonstrations and other related projects are mapped on both the EFFRA Innovation Portal[50].

I4MS, ICT Innovation for Manufacturing SMEs[51], is a European initiative supporting manufacturing SMEs and mid-caps in the widespread use of ICT in their business operations. Under I4MS, SMEs can apply for technological and financial support to conduct small experiments, allowing them to test digital innovations in their business via open calls. I4MS provides information on in-demand digital skills and training materials, training catalogues[52], application experiments[53], Digital Innovation Hubs and competence centres[54].

The **World Economic Forum** platform 'Shaping the Future of Advanced Manufacturing and Production'[55] has set up the Global Lighthouse Network[56]. This community of manufacturers shows leadership using Industry 4.0 technologies to transform factories, value chains and business models, for compelling financial and operational returns. The reports show results and industrial use cases for digitisation across the end-to-end value chain, including manufacturing. These use cases are applications of one or multiple technologies in a real production environment to address a business problem.

6. Technologies for manufacturing digitalisation

Manufacturing digitalisation in its broadest term refers to the application of digital information from multiple sources, formats or owners, for the enhancement of manufacturing processes, supply chains, products and services. Physical items, multiple processes, customer orders, material flow and related data starting from customer needs are connected.

In Industry 4.0, data and analytics are the core capabilities. Table 1 summarises the digital technologies that are contributing to i) the digitalisation and integration of vertical

[47] www.adma.ec

[48] https://www.effra.eu/

[49] https://portal.effra.eu/wiki/909

[50] https://www.effra.eu/effra-innovation-portal

[51] https://i4ms.eu/

[52] https://trainings.i4ms.eu/Trainings

[53] https://i4ms.eu/experiments

[54] https://i4ms.eu/dihs

[55] https://www.weforum.org/platforms/shaping-the-future-of-production)

[56] https://www.weforum.org/projects/global_lighthouse_network

and horizontal value chains, ii) the digitalisation of product and service offerings and iii) digital business models and customer interfaces.

The availability of more and better data lies at the core of today's digital product and production technologies. Digitalisation enables efficient use of automation technologies (e.g. robotics, 3D printing) and process optimisation with machine learning (ML) and can support human operators with augmented reality (AR) and wireless wearable technologies. Information integration and sharing is the key to an efficient value chain and distributed manufacturing. Data are central in product and process design, process control and optimisation, coding and the tracking of products within a firm and along its supply chain. ICT such as cloud, edge, IoT, 5G, Big Data analytics, AI, ML, simulation, visualisation and other interactive, collaborative technologies are emerging trends also in the manufacturing domain.

Table 1. Digital technologies contributing to Industry 4.0[57]

Industry 4.0	Digitalising and integrating vertical and horizontal value chains	Cloud computing and ubiquitous computing
		Mobile devices
		IoT platforms for real-time remote monitoring, up to digital twin reproduction
	Digitalisation of product and service offerings	Augmented or mixed-reality and wearables
		Multilevel customer interaction and customer profiling
		Big data analytics and advanced algorithms including AI, ML and process automation
		Smart sensors and dynamic simulation capabilities
	Digital business models and customer interface	3D or 4D printing
		Authentication and fraud detection for cybersecurity
		Advanced human–machine interface including cognitive and physical enhancements
		Location detection technologies including spatial computing and geotracking

AI is one of the prominent technologies creating entirely new opportunities for the flexible, efficient production of increasingly customized products in small batch runs. AI can have a significant role in manufacturing processes, quality control, shortening the design time, reducing material waste, improving production reuse and performing predictive maintenance.

For the efficient optimisation of resources operations and workflow, real-time status information is essential. Operative systems, Supervisory Control and Data Acquisition (SCADA), Manufacturing Execution System (MES) or Manufacturing Operations Management (MOM), Industrial Internet of Things (IIoT) and other sensor systems must be interoperable with business IT systems, ERP, CRM and Supply Chain Management (SCM), including external systems of value chain partners.

Digital manufacturing platforms enable the provision of services that support manufacturing, e.g. collecting, storing, processing and delivering data. These data either describe the manufactured products or are related to the manufacturing processes and assets that make manufacturing happen, such as material, machine, enterprises, value networks and – not to forget – factory workers. The services are aimed at optimising

[57] https://www.pwc.ru/en/publications/industry-41.html

manufacturing from different angles: production efficiency and uptime, quality, speed, flexibility, resource-efficiency, etc.

Similar findings elsewhere of digitalisation tools needed in manufacturing SME were identified by a UK-based survey[58]. The SME needs are classified into the groups 'data capture and information display' and 'data analysis and decision'. Typically, the data distribution and capture at the SME factory floor is based on paper and manual data entries of the isolated ICT systems. The analysis and decision-making is based on human expertise. The common methodology is using multiple, independent spreadsheets.

Interoperability of information systems is a key issue, as there are heterogeneous systems, such as various engineering systems, manufacturing operative technology systems and all information technology systems at the business level, including suppliers and customers. Standardisation of interfaces is essential as well as data typology and the role of data in different product lifecycle phases[59].

Manufacturing SMEs can commit to digital manufacturing and design with investments that will provide value to their customers such as[60]:

- Data-driven production planning
- Automated data exchange with customers and suppliers
- Design tools that bridge manufacturing processes
- Automated machine data capturing and analysis
- Cybersecurity protocols for equipment, employees and the overall enterprise

The actors around a manufacturing company are presented in Figure 10. The network of actors includes various suppliers and providers as well as a way to contact the customer directly via logistics and the distributor or a marketplace. In the future, any manufacturing company will need to interact with its suppliers and providers through a common interface. This will generate added value and efficiency to the networks in the manufacturing sector.

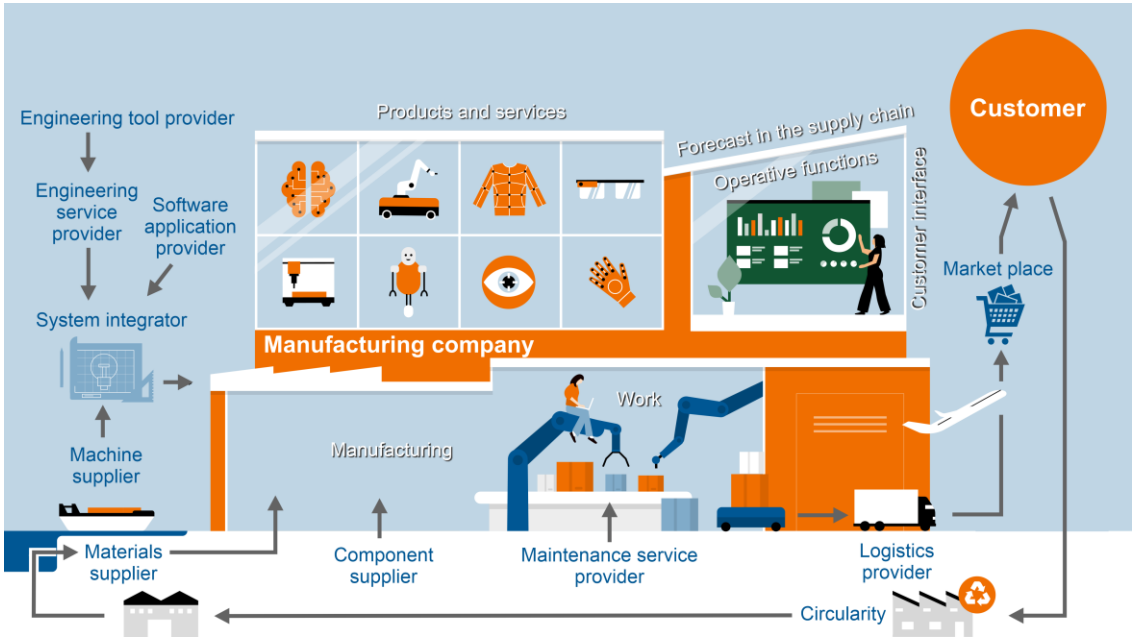

Figure 10. The actors around a manufacturing company are presented with blue entity names.

[58] https://doi.org/10.1007/978-3-030-27477-1_22

[59] https://cris.vtt.fi/ws/portalfiles/portal/26703022/HACI_DataTypology_ResearchReport_SIGNED.pdf

[60] https://www.nist.gov/blogs/manufacturing-innovation-blog/digital-manufacturing-small-manufacturers

7. Prepare for the digital and sustainable future

In Finland, the price of human work is high. In order to survive in the global competition, it is necessary to convert human tasks to robots or robot process automation (RPA). RPA can efficiently carry out tasks that are straightforward and do not require human intelligence. Markets are global and thus the products and services need to be available 24/7. This implies setting up web shops and e-services. Digitalisation will also change the business models of companies. Companies need to constantly discover opportunities for new products, services and partners to stay competitive.

The sustainability of the industry is a rising value. The European Commission has agreed on the Green Deal[61] and is willing to invest in the transition to a climate-neutral, green, competitive and inclusive economy. During spring 2020, the Technology Industries of Finland (Teknologiateollisuus) published a roadmap to the zero-carbon industry[62]. According to the roadmap, digital solutions need to address the entire lifecycle of the industry as follows: raw materials and energy; production and processing; usage, maintenance and logistics; recycling.

On the other hand, we all know that ICT solutions need electricity and big-data centres require efficient cooling systems. The Association of Electrical Engineers in Finland (Sähköinsinööriliitto)[63] reports that greenhouse gas emissions in the ICT sector arise especially from electricity consumption. Whereas carbon footprints describe the emissions and negative climate impacts of products or organisations, carbon handprints show the positive impact that the product or organisation can create[64]. The aspects of sustainability are environmental, economic and social wellbeing. The sustainability aspects in manufacturing include technologies like modelling, simulation, optimisation, visualisation, AR/VR, additive manufacturing, ML and AI.

Table 2. Three development phases (Envision, Enable and Enact) mapped with the maturity levels.

Maturity level	**Envision**	**Enable**	**Enact**
Detailed Business Model	Future challenges	Road map also includes disruptive product/service ideas	Ambitious project portfolio where some failures are potential, but the expected rewards are high
Transform	Opportunity map described for I4.0	Customer segments and expectations, MVP, technologies and resources defined	Actual and future project portfolio
Defined	Develop understanding with specific capabilities and resources	Customer segments, expectations and value proposition defined	Projects evaluated and resource and collaboration needs identified
Managed	Company-specific Industry 4.0 vision	Customer segments and expectations defined	Portfolio of projects without prioritisation
Initial	Company-specific vision does not exist		

[61] https://ec.europa.eu/commission/presscorner/detail/en/ip_20_17

[62] https://teknologiateollisuus.fi/fi/vaikutamme/kestava-kehitys/teknologiateollisuuden-vahahiilitiekartta-ratkaisuja-ilmastohaasteeseen

[63] https://www.sil.fi/uutiset/ict-alan-kaksi-puolta-ict-ala-kuluttaa-energiaa-ja-materiaaleja-mutta-vie-myos-kohti-hiilineutraalia-yhteiskuntaa/

[64] https://projectsites.vtt.fi/sites/handprint/www.vtt.fi/sites/handprint.html

The 3E model[65] combines practically the development phases and maturity levels towards Industry 4.0. Their development phases are: Envision, Enable and Enact. In the first phase, Envision, the understanding of Industry 4.0 is gained and capacities and resources are analysed. In the second phase, Enable, the roadmap is built and the requirements and technologies are identified. The third phase, Enact, implements training, risk management and development projects. These phases are mapped to the maturity model with five levels: initial, managed, defined, transform and detailed business model. The matrix of development phases and maturity levels is presented in Table 2.

8. Summary

Manufacturing companies have noticed megatrends – from digitalisation to the imperative of environmental sustainability and globalisation – and have begun investing in projects that exploit data. Digitalisation is setting the stage for change. Rapid growth has been driven by improvements in ICT and a dramatic increase in the ability to gather, process and transmit data. The fastest-growing firms are those that not only harness information but also possess an ability to transform it into valuable products and services. Once created, information can be distributed at a very low cost, which changes the cost structure of firms on the supply side[66].

Many companies struggle to embrace the digital revolution and the uptake of Industry 4.0 or advanced ICT. The main challenges and barriers to overcome are limited understanding, insufficient resources and the gap in bringing these ideas into practice (Figure 6).

The three-phase model (Envision, Enable and Enact) is a promising process model (Table 2). As in our focus on digitalisation, the DigiMove matrix is a good wake-up tool delivering immediate development ideas and thus also a starting point for the digitalisation pathway of a manufacturing SME (Table 3). The matrix has five maturity levels as columns: Business-as-Usual, i.e. the current normal, Developed, Integrated, Forerunner and Beyond-the-Obvious (future potential). The rows represent the potential objects of digitalisation: Manufacturing, Products and Services, Work, Foresight in Supply-Chain, Customer Interface and Operative (Support) Functions (Figure 11).

Table 3. DigiMove matrix, the wake-up tool for the digitalisation pathway of manufacturing SMEs.

	Business-as-usual, current normal	**Developed**	**Integrated**	**Forerunner**	**Beyond-the-Obvious**
Manufacturing					
Products and services					
Work					
Foresight in supply chain					
Customer interface					
Operative functions					

In the DigiMove matrix (Table 3), there is also an imaginary-case application, where one maturity level has been selected for each operational level based on the description of

[65] http://www.jiem.org/index.php/jiem/article/view/2073

[66] https://www.weforum.org/reports/towards-a-new-normal-new-design-rules-for-advanced-manufacturing-business-models

the digital solutions applicable for each cell. The selection visualises that the development ideas and actions should focus on work and operative functions before proceeding with products and services or customer interface.

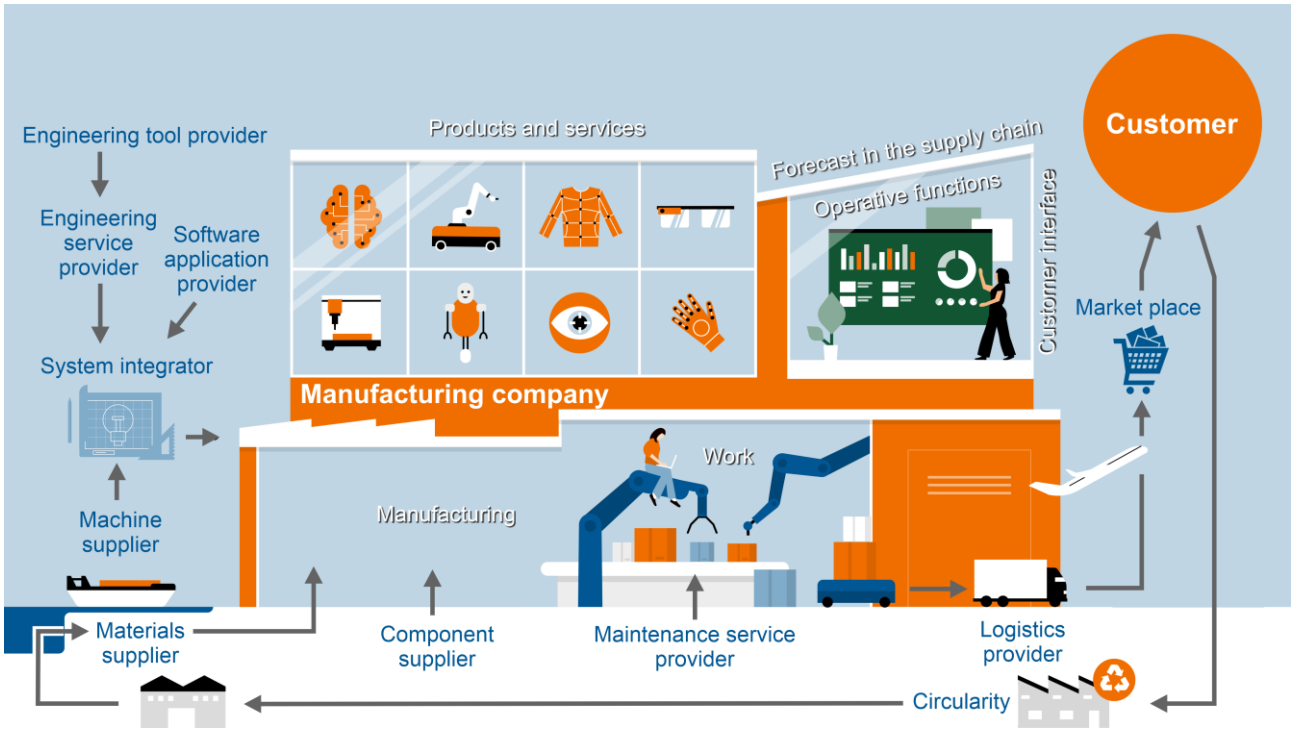

Figure 11. The digitalisation of a manufacturing company can focus on the operational levels (Manufacturing, Work and Operative functions), their results (Customer Interface, Products and Services) or the integration with the actors in the wide supply chain.

This matrix, together with the supported phase model, will help Finnish manufacturing SMEs to proceed in their digitalisation pathways. The VTT service provision for the customised (self-adaptable) digitalisation pathways will be proposed in the next report!