DIGITAL INNOVATION PROCESS GUIDE

HANDBOOK FOR MANUFACTURING SMEs

60 YEARS APO 1961–2021
Asian Productivity Organization

The Asian Productivity Organization (APO) is an intergovernmental organization committed to improving productivity in the Asia-Pacific region. Established in 1961, the APO contributes to the sustainable socioeconomic development of the region through policy advisory services, acting as a think tank, and undertaking smart initiatives in the industry, agriculture, service, and public sectors. The APO is shaping the future of the region by assisting member economies in formulating national strategies for enhanced productivity and through a range of institutional capacity-building efforts, including research and centers of excellence in member countries.

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DIGITAL INNOVATION PROCESS GUIDE

HANDBOOK FOR MANUFACTURING SMES

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Digital Innovation Process Guide
Handbook For Manufacturing SMEs

Dr. Eva Diedrichs served as the volume editor.

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FOREWORD

Manufacturing SMEs, which are the backbone of industrial development, are on a fast-growth trajectory in APO economies. However, amid the rise of Industry 4.0, only a small fraction of SMEs has adopted digital technologies and digitalization processes. SMEs must embrace digital innovation to enhance efficiency, meet international quality standards, and strengthen their position as competent suppliers for the global market.

The APO is publishing the *Digital Innovation Process Guide: Handbook for Manufacturing SMEs* not only to support the digital transformation process but also to tackle survival challenges posed by the COVID-19 pandemic. The process guide including its conceptual framework, tools, and templates was developed and tested in manufacturing SMEs in participating countries. The results confirm the opportunities resulting from digital innovation in SMEs in the sector, especially during the current pandemic. Digital innovation radically improves operational parameters such as efficiency, productivity, quality, cost, delivery, and flexibility. Increasing product value, predicting market trends from data analytics, and reducing time to market for new offerings are only a few examples of the benefits. Furthermore, digital innovation can potentially alter industry boundaries, produce new business models, and support novel methods of producing goods and services during the COVID-19 pandemic.

This *Digital Innovation Process Guide: Handbook for Manufacturing SMEs* is intended to serve as a resource for SME managers and business advisors on their innovation journey through digitization and digitalization. The contributions and commitment of the experts team led by the Chief Expert, Dr. Eva Diedrichs, in this research project are very much appreciated by the APO.

Dr. AKP Mochtan
Secretary-General
Asian Productivity Organization
Tokyo, September 2021

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The endeavor of the Chief Expert, Dr. Eva Diedrichs, in developing the methodology framework and guiding the research team is recognized. Insights provided by the experts to refine the *Digital Innovation Process Guide: Handbook for Manufacturing SMEs* are worth mentioning. Support of more than 100 companies across APO member countries in the pilot test of this project is acknowledged.

Without their contributions, this publication would not have been completed.

1. BACKGROUND

The Fourth Industrial Revolution, characterized by increasing digitization, connectedness, and operational integration, has fundamentally transformed production systems in companies across global value chains. While large businesses have been quick to make the transition to the digital world, the majority of SMEs in the manufacturing sector, which form the backbone of industrial development, are yet to adopt digital technologies and digitalization of the processes, products, and business models. SMEs in APO member countries are no exception. Although they are on a fast-growth trajectory in APO economies, only a small fraction of them have access to the information and communication technologies (ICTs) commonplace in larger enterprises. They face numerous challenges in staying competitive in global value chains.

'Research on Industry 4.0 Digitization Strategies for SMEs' was conducted in 2017 to assess the status, readiness to adopt, and initiatives related to Industry 4.0 at national levels. Although the different economic situations of the participating countries led to different approaches, there were commonalities in the needs of SMEs in preparation for Industry 4.0 digitalization. These needs included need for greater awareness of the benefits of Industry 4.0 digitalization among all stakeholders and improved access to the internet, advanced technologies, and funding for digitalization initiatives.

The research, which was performed in 2018, also showed that SMEs must embrace digital innovation to enhance efficiency, meet international quality standards, and strengthen their position as competent suppliers for the global market. Even though SMEs are willing to adopt new technologies to scale up their businesses and are aware that digitization and digitalization are of prime importance, there are many barriers to overcome. A strategic focus on the integration of advanced technologies for digital transformation is needed. The lack of digital capabilities and knowledge of cybersecurity prevents many SMEs from taking advantage of Industry 4.0. Defining the starting point is another difficulty. SMEs in the manufacturing sector seem to be more reluctant than their peers in other sectors. Top management plays a key role in leading digital innovation agendas. To support SMEs in the process of digital transformation for Industry 4.0, the Center of Excellence on IT for Industry 4.0 and the APO aimed to publish an approach paper guiding SMEs in manufacturing in undertaking digital innovation. Against that background, the APO initiated the project to develop a *Digital Innovation Process Guide: Handbook for Manufacturing SMEs*.

Research on the current digital innovation performance of manufacturing SMEs was conducted in 2020 in India, Singapore, the Republic of China (ROC), and Vietnam. The results confirm the business potential resulting from digital innovation in manufacturing SMEs, e.g., increase the product value, predict market trends from data analytics, and reduce the time-to-market for new offerings. Digital innovations have radically improved excellence in operational parameters, such as efficiency, productivity, quality, costs, delivery, and flexibility. Furthermore, they have the potential to alter the industry boundaries, producing new business models. Across all industries, there is a clear

indication that the digital technologies that underpin the Fourth Industrial Revolution are going to have a positive impact on the business environment. A key trend is the advancement of technology-enabled platforms that amalgamate both demand and supply to disrupt existing industry structures. The mobile technology platforms are fashioning completely novel ways of consuming goods and services during the pandemic. In addition, they are lowering the obstacles for businesses and individuals to generate wealth, changing the personal and professional environments of workforces. Overall, the inevitable shift from simple digitization to innovation grounded in amalgamations of technologies will force businesses to reexamine their approach of doing business.

To leverage the potential for sustainable growth and competitiveness of manufacturing SMEs coming from digital innovation, the *Digital Innovation Process Guide* (DIPG) has been developed with the support of national experts from APO member countries. Its conceptual framework, tools, and templates have been tested in almost 100 manufacturing SMEs in India, Singapore, the ROC, and Vietnam. Different manufacturing industries have been covered, including electrical and electronics, medical devices, casting, forging, sheet metal, sheet metal parts manufacturing, food and beverages, optical equipment, pharmaceutical manufacturing, and personal mobility device manufacturing, among others. During the test phase, additional tools, case examples, and lessons learned have been added. Thus, the DIPG has become even more valuable for SME managers and business advisors in their efforts to drive innovation through digitization and digitalization in manufacturing SMEs.

2. OBJECTIVE OF THE DIGITAL INNOVATION PROCESS GUIDE

This *Digital Innovation Process Guide: Handbook for Manufacturing SMEs* is designed to

- leverage the business potential of digital innovation in manufacturing SMEs and increase their competitiveness and sustainable growth;
- support business advisors and managers in manufacturing SMEs to facilitate the successful development and implementation of the digital innovation process within manufacturing SMEs;
- contribute to the digital transformation of manufacturing SMEs;
- increase the manufacturing SMEs' agility to connect and integrate into (new) value networks;
- motivate managers in manufacturing SMEs to engage in the digital innovation process to secure their organization's future competitiveness and sustainable growth;
- provide practical tools and templates suitable for manufacturing SMEs;
- develop the SME management's knowledge and practical experience in digital innovation and digital innovation project management;
- increase the awareness of digital innovation benefits for manufacturing SMEs as well as for manufacturing industries and value networks; and
- address the challenges in the digital innovation process with appropriate measures.

In many countries, the COVID-19 pandemic, with the requirements of social distancing and lockdowns, has stimulated digital innovation. With digitalization, not only activities or internal processes are innovated at manufacturing companies, integration within value networks also increases and new digital business models evolve. For example, automotive suppliers become suppliers of mobility solutions and manufacturers of medical devices evolve into smart healthcare suppliers. [1]

This DIPG builds on a context-oriented and learning-driven conceptual model. The contexts relevant for SMEs' digital innovation are the often-uncertain environments and their digital innovation ecosystems. Such an ecosystems includes the enterprises, the SMEs' customers, the service providers to the manufacturing SMEs, the investors, and the academia and policy makers, among others. The ecosystem is embedded in an environment of uncertainty. Proficiency in digital innovation in manufacturing SMEs will help to succeed in such an environment. To develop their knowledge in digital innovation, managers of manufacturing SMEs will need success stories, and

possibilities to gain experience in digital innovation themselves. The *Digital Innovation Process Guide: Handbook for Manufacturing SMEs* will help them to

- develop the digitalization vision and define the level of ambition regarding their digital innovation process;
- identify strategic triggers for the SMEs to adopt digitization and digitalization in their operations;
- define the current proficiency of the digital innovation process in manufacturing SMEs;
- define customized actions that will support the manufacturing SMEs in digitalization for sustainable growth; and
- provide a first set of tools for business advisors and managers of manufacturing SMEs to facilitate the implementation of digital innovation processes.

3. METHODOLOGY

The DIPG builds on

- a conceptual framework that takes the uncertain environment and the digital innovation ecosystem into account;
- the *Digital Innovation Canvas* that stimulates a learning-by-doing approach to enhance the SME management's proficiency in digital transformation;
- selected tools to develop a bespoke digital innovation process suitable for the respective SME;
- best-practice examples; and
- the support of experienced business advisors.

This guide to support manufacturing SMEs in developing their digital innovation process is designed for experienced business advisors and managers. It takes the SME's current level of digitalization and their strategic intent as the starting point for a highly customized approach to further develop their digital innovation process. The methodology will be applicable to manufacturing SMEs in different industries and different value networks. The SMEs might serve B2B or B2C markets. A successful application of this methodology will require knowledge of the SME's industry and its level of digitalization today and in the future. It will also require business acumen as well as experience in innovation management and digitalization in the manufacturing industries. The methodology is tested in around 100 SMEs at various levels of digitalization.

3.1. The Digital Innovation Ecosystem Embedded in an Uncertain Environment

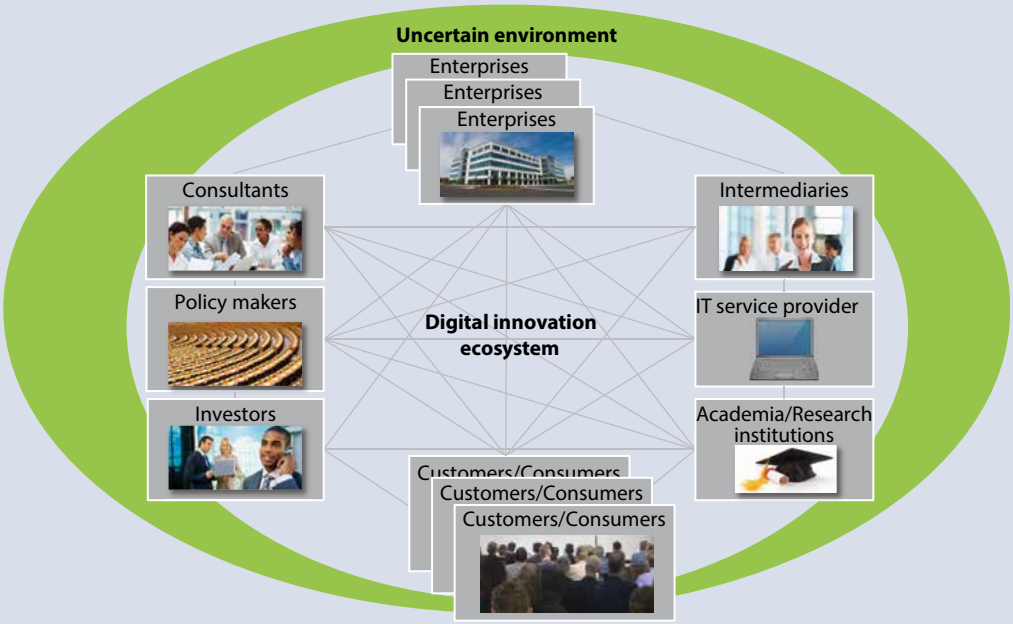
Digital innovation in manufacturing SMEs is not just a challenge for the SMEs themselves. It needs the support of all stakeholders in the digital innovation ecosystem, given the uncertain environment in which digital innovation has to take place (see Figure 1).

3.1.1. Driving Digital Innovation in an Uncertain Environment: SMEs and their Perception of the Environment

According to Bruno and Tyebjee [2], an entrepreneurial firm typically faces a more uncertain environment owing to a lack of access to environmental resources in comparison with large firms. Its administrative structure must be sufficiently flexible to react to these uncertainties and sufficiently skilled to improve access to resources [2]. However, the informal, flexible nature of SMEs gives them an edge in dealing with the uncertain environment in comparison with their larger counterparts.

FIGURE 1

DIGITAL INNOVATION ECOSYSTEM EMBEDDED IN AN UNCERTAIN ENVIRONMENT.



Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Duncan [3] defines environmental uncertainty as

- the lack of information regarding the environmental factors associated with a given decision-making situation;
- not knowing the outcome of a specific decision in terms of how much the organization would lose if the decision was incorrect; and
- inability to assign probabilities with any degree of confidence with regard to how environmental factors are going to affect the success or failure of the decision unit in performing its function.

3.1.2. Uncertain Environment in the Current Context

It is evident from the above that uncertainty is not just a phenomenon of the recent COVID-19 pandemic. It has always been a challenge and an opportunity at the same time for businesses around the world, regardless of their size. Unexpected changes in regulations, customer behavior, supply chains, competitive landscape, trade relationships, technologies, etc., require companies to understand the opportunities as well as the risks. The COVID-19 pandemic, with lockdowns and social distancing in many countries, has affected businesses and disrupted value-networks around the world. The onset of the pandemic has led to lockdowns in many countries, such that the only way of continuing the business was on a virtual basis, by taking advantage of digital technologies. Although the situation has eased somewhat, businesses large and small are finding themselves adopting to new norms of working and getting things done. Organizations that want to survive and succeed in such an environment need to be agile in adapting to and embracing digital technologies and securing their competitiveness through digital innovation.

3.1.3. Key Stakeholders in the Digital Innovation Ecosystem

Embedded in an uncertain environment, manufacturing SMEs are part of the digital innovation ecosystem. Their various key stakeholders have their respective needs and demands for digital innovation. Their customers and suppliers create opportunities and demand for digital innovation and so do the consumers. Consultants; intermediaries such as trade associations, chambers of commerce, or training organizations; and IT service providers offer their support to SMEs in developing competitiveness through digital innovation. Policy makers define the legal and economic framework for SMEs to operate in and develop their digital innovations. At the same time, policy makers offer funding schemes for SMEs to enhance their digital innovation skills and performance. Investors focus on the returns on their investments in SME digitalization. By developing digital innovation, such return on investment is expected to increase. Academic institutions are to ensure the supply of labor force skilled in digital innovation as well as in developing advanced digital manufacturing technologies.

For SMEs in the manufacturing industries, opportunities will emerge to gain from digital innovation. They can improve their productivity, make their products 'smart,' and gain from digital business models, thus opening up new markets and new customer segments. However, digital innovation will require investments in new technologies, products, and business models, among others, as well as in skills and knowledge.

The above-mentioned key stakeholders also play a key role in awareness creation, intervention, experiencing digital innovation, and digital transformation of manufacturing SMEs. They also serve as channels to introduce the benefits of, and steps towards the digital innovation process to manufacturing SMEs. For the development and testing of the DIPG, key stakeholders of the digital innovation ecosystem have been involved to the degree possible. They have contributed both to the development of the conceptual model and the testing of the tools and methods.

3.2. The Conceptual Model

To foster digital innovation in manufacturing SMEs, the conceptual model (see Figure 2) includes four phases that will lead to the desired value from digital innovation. These phases start with the current level of digitization, the awareness creation for digital innovation, and the intervention at the organizations. These then lead to the experience and transformation into a digital-innovation organization and the value creation. Based on the experience and transformation success, feedback can be provided to enhance the impact of planned further interventions.

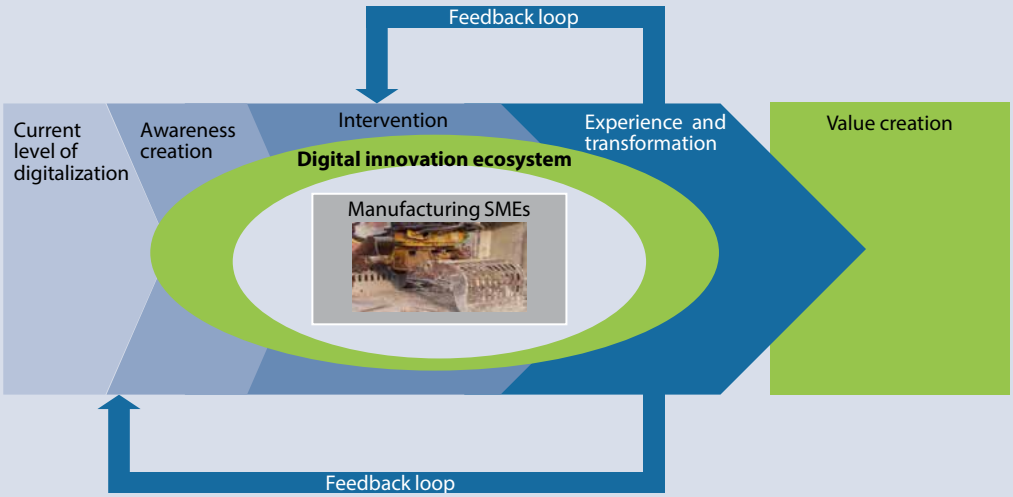
3.2.1. Current Level of Digitalization

In each country, each industry and value network, the level of digitalization adoption is different. In most cases, the level of digitalization in SMEs usually has significant room for improvement. For example, in 2019, 60% of enterprises in the ROC had implemented digital transformation plans, yet only 13% of these SMEs had actually initiated digital transformation-related projects due to resource and budgetary constraints. Manufacturing industries in the ROC have been slow to digitalize, according to Lin-Ya Hong, National Expert for the ROC.

However, manufacturing SMEs that engage in the digital innovation process can achieve a significant productivity gain and sustainable growth. Digital innovations will provide swift and substantial wins in productivity and profitability for a modest capital outlay. In India, we estimate that in certain cases, a moderately small CAPEX investment in the cloud and big-data

FIGURE 2

CONCEPTUAL MODEL TO DRIVE DIGITAL INNOVATION IN MANUFACTURING SMEs.



Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

analytics could translate into a considerable increase in operating profit if executed and supported appropriately. The real-time monitoring of supplier performance has enabled greater visibility in the value chain and ensured 100% on-time delivery of orders. The process interlocking with previously proven process cycle ensured that there is no skipping of the processes. The digital technologies helped reduce the inventory costs by 35%, rejection costs by 50%, quality costs by 45%, maintenance costs by 45%, energy cost by 40%, logistical costs by 30%, and customer defects by 70%; while improving productivity by 25% and overall equipment efficiency by 35% in the evaluated organizations. In addition, in India, the significant achievements were reported as

- 20~35% productivity gain;
- 25 to 50% reduction in quality issues;
- 100% traceability of critical to safety parts and emission parts; and
- 100% adherence of delivery schedules.

In the ROC, several accomplishments were achieved through the process of digital transformation, as the following examples demonstrate:

- **Smart manufacturing in printed circuit boards:** The time taken to eliminate defects has reduced from 30 days to seven days (i.e., there is a time saving of 75%) and the false alarm rate of defect detection has reduced by 50%.
- **Smart manufacturing in the textile industry:** There is an increase of 20% in defect-free units, the success rate of the initial color matching has increased by 5%, and the energy saving is 15%.

- **Smart manufacturing in the aerospace machine tool industry:** It has shortened product delivery time by 30%, increased productivity by 10% and reduced production costs by 10%.

- **Smart manufacturing of servo motors:** It has driven 2.5 times of daily output (increase the units from 150 to 525 units per eight hour a day).

- **Smart manufacturing of water hardware and hand tool industry:** increase 60% of output per capital of labor force (from USD60,000 to USD96,000).

- **Smart manufacturing of automotive and motor vehicle industry:** the total equipment efficiency has been increased from 80% to 85% [4].

3.2.2. Awareness Creation

Often SMEs are not aware of the impact that digital innovation might create for their organizations. They might have a need, but they do not express the demand. Consultants, business advisors, intermediaries (including media), and policy makers are in the position to enhance the manufacturing SMEs' awareness of digital innovation benefits. It is about the lack of knowledge about digital technologies and how they can help achieve business objectives; the risk that the adoption of digital technologies might bear, or the lack of experience in managing a digital innovation project and its related processes. Case examples from successful implementation of digital innovation projects, test labs to experience how digital technologies in manufacturing SMEs work, training centers that offer hands-on practical experience in advanced manufacturing where different digital technologies are applied, are the actors that will help to increase the awareness of manufacturing SMEs to embrace digital innovation. Best practices in awareness creation are provided from India and the ROC, among others.

In India, manufacturing SMEs' attention on digital innovation has been raised via different channels, such as

- webinars organized by the National Productivity Council, by consultants and multinational corporations;

- training on low-cost automation;

- conferences by academics and industries with case studies on topics such as smart machining systems, smart factories, and Industry 4.0 (I4.0) for MSMEs; smart machines, smart tooling, sensor networks, wireless connectivity, intelligent automation and control, advanced robotics, intelligent machining, digital manufacturing, and smart materials for smart devices and machines; artificial intelligence (AI) and machine learning; cybersecurity and challenges in smart factories; augmented reality/wearables; digital twins; cloud computing; and big data analytics;

- research projects on the role of I4.0 in managing the disruptions posed by COVID 19;

- training and workshops on the digital innovation process;

- guidance on 'what is in it for me' in the context of digital innovation;

- 'hand-holding' for low-cost automation solutions; and

- guidance on I4.0 standards, implementation risks, and possible solutions using digital innovation guide.

In the ROC, the Ministry of Science and Technology (MOST) has promoted the AI Innovation Research Program and established four AI research centers, including the Artificial Intelligence for Intelligent Manufacturing Systems Research Center (AIMS). The goal of AIMS is to establish a world-class AI research center that will build on the ROC's traditional strength in manufacturing and make critical contributions to advance it to the next level in the global market. AIMS has coordinated many outstanding research teams and projects in the ROC in the field of intelligent manufacturing, including promising areas and applications such as AI, deep learning, machine vision, machine network, big data analysis, intelligent agriculture, and intelligent machinery. Its vision and mission are to build on the ROC's traditional strength in manufacturing [5] in the following ways:

- **Upgrade and transform current industries in the ROC:** Create opportunities for experts in AI, statistics, manufacturing, management, science and technology, law, social sciences, etc., to work together to promote interdisciplinary research and innovation.

- **Cultivate AI talents in the ROC:** Collect and maintain manufacturing big data, organize AI competitions for intelligent manufacturing solutions, and utilize these events to train or cultivate AI talents that will help enhance competitive advantages and profitability of the domestic industries.

- **Build partnerships between academia and industry for innovation and entrepreneurship:** Establish strategic alliances with industry associations and institutions, integrate and utilize academic resources, bring in domestic and foreign venture funds, and accelerate the growth of startup companies.

- **Elevate the ROC's global visibility and influence in AI:** Build on the ROC's strength in manufacturing to promote cooperation with leading research centers and multinational companies worldwide, and invite domestic and foreign experts to interact, share, and collaborate.

- **Export effective AI solutions for intelligent manufacturing:** Promote the development and application of advanced technologies in AI in the field of intelligent manufacturing, help the domestic industries to adopt AI or even create a brand-new AI industry, and export these technologies to other countries.

3.2.3. Intervention

The manner in which digital innovation is embraced will be different in each organization. The intervention at an SME should start with a clear vision of the SME's management regarding the organization's digitalization. Based on this, a modular approach is suggested for the digital innovation process. The modules will form the basis for developing the digital innovation process, allowing for focus on the digitalization vision. At the same time, allocating the resources and managing the risks of each digital innovation project in line with the expected business impact will increase the learning from each digital innovation project. This will also continuously improve the organization's digital innovation process. Clear, measurable indicators have to be defined at the beginning of the digital innovation process. This is essential to evaluate the digital innovation project's business impact. Furthermore, the SME gains insights for its next digital innovation project.

With each digital innovation project, the SME will be able to refine its digital innovation process. Ideally, this leads to digital transformation of the organization, including its management, organizational structures, and culture. With digitalized manufacturing, and also potentially smart products and services, mass customization, leaner processes, and digital innovation as key elements of the organizational DNA, SMEs will generate higher value and hence gain in competitiveness.

In India, in a few cases, original equipment manufacturers are helping SMEs with (1) development of low-cost solutions using robotic arms; (2) cloud solutions in areas of auditing, *kaizen*, maintenance, and productivity; (3) supplier quality and improvement monitoring; and (4) connecting with supplier systems in the cloud. The fundamental dilemma is that SMEs are not sure if, when, and in what way they should initiate digital innovation activities. Moreover, the role and importance of each of the various enabling technologies are still abstract and need to be prioritized. Top management of some SMEs in industries such as food, electrical and electronics, and medical equipment manufacturing highlighted the need for thinking out of the box and accelerating the adoption of I4.0 technologies for sustainability.

Since its foundation in 1965, a metal manufacturer in the ROC mainly manufactured low-end grade 3 locks, which would yield low profit margins. As the market's price competition was fierce, the company decided to shift focus to grade 1 and grade 2 locks that must meet quality and fire resistance certifications with a high technical threshold. The company, which has over 50 years of technical expertise in the field, applied digital innovation technologies to facilitate interdisciplinary cooperation with the electronics, communications, and biometrics industries to successfully develop smart-lock products, which in the future will be integrated into the IoT market for smart home and smart building applications.

In order for the traditional lock manufacturing company to transform and upgrade to a technological security system company in the modern digital era, it has set long-term goals and action plans for the next 10 years. The company also invested a lot of money in the construction of its in-house testing and research facility that complies with international standards for high product quality and outstanding reliability. The differentiation in product design constantly strengthens its design and manufacturing capabilities as well as its marketing strategies. The digital transformation process aimed at serving high-end markets with small volumes, large variety, high technical thresholds, and few competitors resulted in steady yearly profit gain and growth over the past 20 years, as per Lin-Ya Hong, National Expert, ROC.

3.2.4. Experience and Transformation

Experience gained from digital innovation projects will contribute to the continued development of the digital innovation process. The more the SME adopts digital innovation as a means to create value the more it also stimulates the transformation as a digital innovation 'champion.' Digital innovation shapes the entire organization, its products and services, processes, business models, technologies, organizational structures, leadership and management approaches, and its culture.

In India and in other countries, digital technologies are the prerequisites for 'lights-out' manufacturing, which denotes an entirely automated work setting. While human beings and machines work together in a smart factory, dark factories do not require a human workforce on the sites. The idea of a completely functional industrial unit with minimum of human workforce may help to continue production without any constraints, especially during pandemics such as COVID-19. In the present time, digital technologies in India are perceived as a means to ensure continued operational activities while at the same time minimizing the risks associated with

coronavirus transmission. These technologies are also helping businesses to advance newfangled models and transform into more resilient industries in the medium-to-long term. Cloud manufacturing, which is one of the I4.0 technologies, helps in real-time tracking of input material, raw materials, child parts, work in progress, and finished goods. Additive manufacturing is not only helping in rapid development but also in 3D printing of spare parts, which are not available due to disrupted supply chain, especially in the medical-equipment SMEs. Furthermore, augmented reality is being planned. During the interaction with 30 SMEs, it was identified that automation and restoring can enable organizations to become flexible while managing risks of COVID-19. Medical device industries in India are passionate about embracing newfangled technologies to scale up their businesses. They are mindful that digital technologies of I4.0 are on the top management's agenda. These technologies have the capability to drastically transform the processes and systems of the widespread value chain of the organizations. I4.0 ensures seamless connection of the physical and digital domains, says Sanjiv Narula, National Expert, India.

CASE STUDY: ROC

Established in 1982 in the ROC with a wide range of product offerings, the metal manufacturing company was facing issues related to wage increase, talent shortage, and supply shortage. These were the driving factors for the company to invest in digital technologies and automated production line to provide better quality and service to the market. The first digital innovation project on automated production failed due to the shortage of digital talent and the lack of prioritizing the vision and action plans. Yet, in 2017, the company proposed a 5–10 years blueprint, took a series of steps to expand its factory size, and successfully adopted the digital innovation technologies toward an automated product line and an automatic welding robot to increase manufacturing ability and ensure product quality, Lin-Ya Hong, National Expert, ROC, highlights.

Nowadays, automated production and robots are extensively used in the manufacturing industry and have become an essential element in the manufacturing processes. Many manufacturers depend on adaptable robots to improve the productivity and quality of the products. The introduction of automation in the manufacturing process has enhanced the quantity of production and also reduced a major part of labor cost.

Today, the company's production lines only require less than three workers to supervise the operations of the fully and semi-automatic manufacturing, assembly, and packaging of the products. The company basically can make baking trays or loaf pans automatically or semiautomatically. The production capacity has increased three times compared to the original production volume. While customer priority, quality orientation, and product innovation comprise its mission for the digital transformation, the company is also devoting a lot of effort to strengthen its brand image and continuously provide the best products and services to the domestic and international markets, emphasizes Lin-Ya Hong, National Expert for the ROC.

3.2.5. Feedback

Experiences gained from the digital innovation projects are critical for the SMEs and the digital innovation ecosystem to learn from. Therefore, feedback is essential not only internally to the next digital innovation project, but also externally to the outside world. The external entities may be the digital innovation training center, the related service or technology provider, or the SME's suppliers and/or customers.

For example, a Taiwanese SME in the electric and machinery industry has developed and applied smart manufacturing technologies to produce high-efficiency motors with high quality. One of the smart manufacturing technologies the company launched is the sensors and image-recognition technology. It can precisely detect the amount of wear during the stamping process and thus reduce the cost of production disruption because of a malfunction. Further, the company has implemented an intelligent manufacturing approach to the painting process in which the painting designated for each specific piece is applied automatically according to the work order.

The production lines are also equipped with sensors that can detect abnormal temperatures and vibration. All data is transmitted to the management system, which enables employees to recognize and solve issues in a timely manner. The employees can monitor the status of the smart production lines through smart phones and iPad devices. The plant manager can supervise the operations remotely also on mobile devices.

Smart manufacturing has created a positive and reciprocal feedback cycle for the company to realize a reduction in defect rate, reduce the amount of machinery equipment used, and save the consumption of energy and materials. This leads to an increase of sales and profitability, as noted by Lin-Ya Hong, National Expert, ROC.

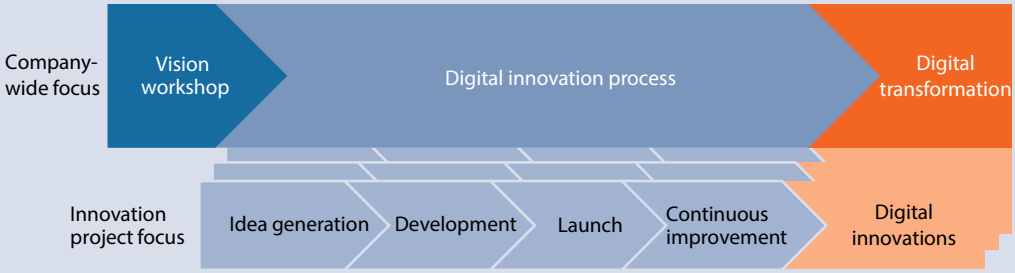
3.3. The Digital Innovation Process

When introducing the concept of the 'digital innovation process' to SMEs, two different levels (see Figure 3) are to be taken into account. The digital innovation process on a company level aims at the digital transformation of the entire organization. The digital innovation process on a project level will lead to digital innovation as an output. This output may be in the form of smarter products, a digital business model, digitally connected machines, digitalized process steps, or an entire process, such as the maintenance process. The sum of the digital innovation projects should lead to the digital transformation of the organization as defined in the digitalization vision of the SME.

Within the digitalization process on a company or a project level, the general steps follow a similar logic: from idea generation and management to the development of the idea; the successful launch of the new product/service, process, or business model; and their continuous improvement. In line with these innovations, often the change in the organization's strategy and culture takes place, which in turn leads to the digital transformation.

FIGURE 3

THE TWO DIMENSIONS OF A DIGITAL INNOVATION PROCESS.



Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

3.4. *Digital Innovation Canvas*

When stimulating the SME's focus on digital innovation, one should take into account the key drivers and enablers for digital innovation. They have been integrated in the *Digital Innovation Canvas*, which offers a structured and interactive approach to digital innovation for the SME's management and their business advisors. The development of the *Digital Innovation Canvas* (see Figure 5) is embedded in a journey from developing a digital innovation vision to defining the digital innovation project(s) and the digital innovation process that will lead to the expected value from digital innovation. This *Digital Innovation Process Guide: Handbook for Manufacturing SMEs* describes the SMEs' journey. It has been developed and tested in India, the ROC, Singapore, and Vietnam with local SMEs. It allows a highly interactive approach engaging the SMEs' key actors. Each step in this approach is designed to create clear value for the SME.

3.4.1. Digital Innovation Vision as the Starting Point

In the first phase, the SME will be supported to develop its digitalization vision (see Figure 4) as a basis for developing the digital innovation process for the organization. This will help identify triggers for the digital innovation process and the specific digital innovation projects in line with the SME's ambition, resources, and competitive context.

FIGURE 4

KEY CRITERIA FOR SMEs' DIGITALIZATION VISION.

SMEs' digitalization vision.

The SME's digitalization vision

- defines the optimal desired future state of what an organization wants to achieve over time;
- is understood and shared by all employees;
- is broad enough to encompass a variety of perspectives;
- is easy to communicate;
- is inspiring and uplifting;
- is concise and inclusive; and
- may be 'action-oriented' or 'outcome-oriented.'

Source: IMP^{3}rove [19].

The digitalization vision will be developed in a highly interactive workshop setup. The participants will include the SME manager and his/her management team. A business advisor will guide the process to ensure that the vision is ambitious enough given the competitive environment, yet realistic as well, given the SME's digital innovation capabilities and resources. Other key stakeholders, such as key customers or contract manufacturers, may be invited too.

Building on the digitalization vision, the *Digital Innovation Canvas* will guide the discussion and actions for enhanced digital innovations.

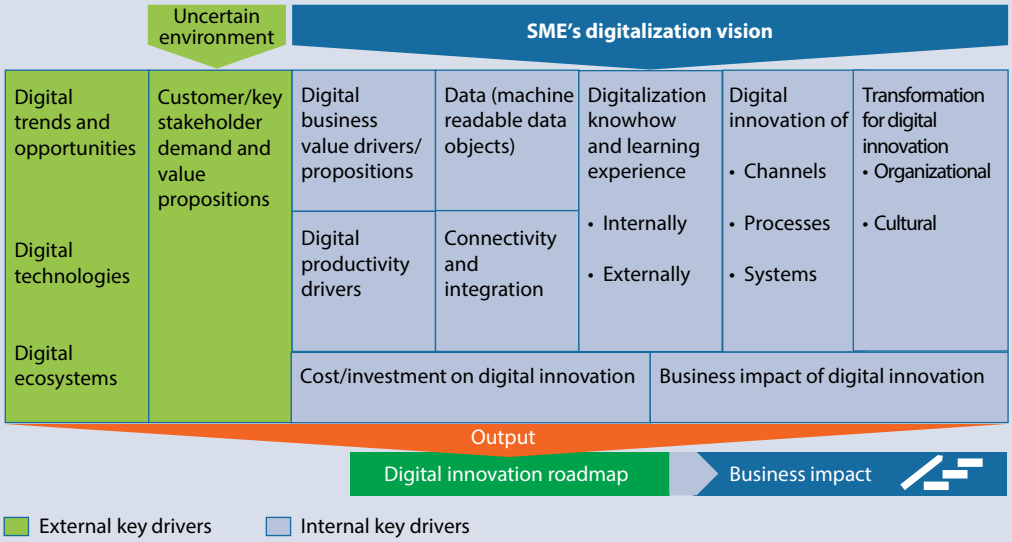
3.4.2. The *Digital Innovation Canvas* and Its Key Drivers for Digital Innovation

The *Digital Innovation Canvas* (see Figure 5) engages manufacturing SMEs in replacing traditional manufacturing technologies, processes, structures, systems, and management approaches with digital innovations. It draws the SME management's attention to the current digital trends and

opportunities, digital technologies and ecosystems, customers and key stakeholders, and their current demand for digital innovation and value propositions, in the outside world. All that is also influenced by the uncertain environment.

FIGURE 5

DIGITAL INNOVATION CANVAS.



Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

At the same time, the *Digital Innovation Canvas* supports the SME management in analyzing the organization's current performance in digital innovation in the light of its digitalization vision and externally available digital approaches, technologies, trends, and customer demand. During this analysis, new ideas and opportunities will emerge for further digitalization of value propositions (such as smart products or services) or of productivity gains by applying machine-to-machine communication, for example.

For value added, the use of digitized data, and in some cases digitalized data objects too, can be identified as promising options for manufacturing SMEs. The same is true of connectivity and interoperability within the organization and/or integration within the value networks and with digital innovation partners.

There may be limited digitalization knowhow and learning experience within the SME organization. However, these can be complemented by external sources. Digital manufacturing labs, training centers, etc. can support SMEs in gaining knowledge in digitalization. Discussing the current level of digital knowhow in relation with the SMEs' digitalization vision, customer/stakeholder demand, and available digital technologies, and comparing it with future requirements, will reveal skill gaps within the SME organization. These gaps can be closed by complementing traditional manufacturing skillsets with more advanced skills such as data analysis and system integration.

Developing digital channels to reach different customer segments or markets has an impact on a number of other business processes such as invoicing, financial planning, etc. Integrating with other processes such as design and engineering, production management, quality management,

maintenance management, and logistics is a major task with a significant productivity gains risk, yet also with a high potential. Therefore, the digital innovation process of a manufacturing SME should always follow a modular approach. What gets the first priority is defined by external key drivers (opportunities and competitive pressure), the SME's digitalization vision and ambition, and last but not least by the cost or required investment and available funds and resources.

Engaging in discussion on digital innovation, SMEs will experience, and will have to drive organizational, leadership, and cultural changes. Organizational structures in manufacturing will require less low-skilled workers. On the other side, higher-skilled staff will expect empowerment and less hierarchical leadership approaches. This, plus the fact that more and more decisions might be taken by more autonomous systems, will trigger a cultural transformation in the organization. Skills will need to be developed in advanced manufacturing technologies, digital innovation management, risk management, change management, cybersecurity, and many other areas. Funding for these training programs has to be allocated as well.

The impact of the digital innovation process with its digital innovation projects is measured by the business impact achieved. This is measured in terms of increase of profit, revenue, market size, productivity gains, and overall competitiveness, compared with the cost and investment required for the digital innovation process.

The development of a *Digital Innovation Canvas* will yield the use of digital technologies to speed up processes, develop digital services, make products smart, or even to gain value from a digital business model. Practice has shown that SMEs might start filling the *Digital Innovation Canvas* based on the current situation. In a second step, they can define what their desired status should be in given time frames. This, then, will lead to the digital innovation roadmap, and the continued development of the digital innovation process.

3.5. Process Steps to Support SMEs in Using the *Digital Innovation Canvas*

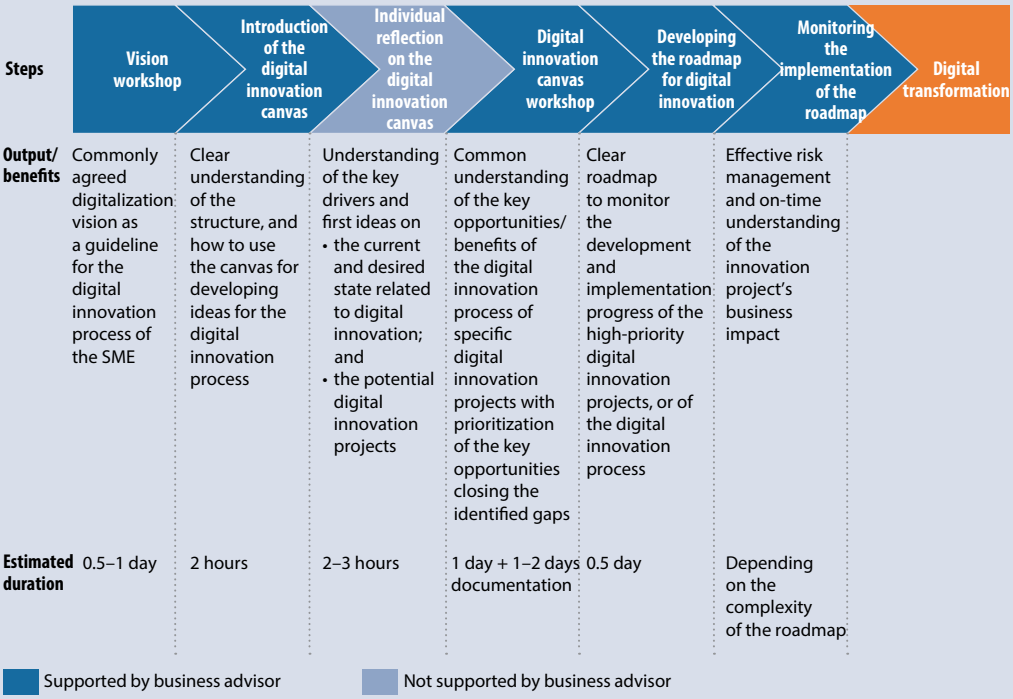
Working with the *Digital Innovation Canvas* is an iterative process that will surface digital innovation opportunities. By leveraging the *Digital Innovation Canvas* for the entire organization, and/or for individual digital innovation projects, the management will gain experience in taking all key drivers into consideration. Working with the *Digital Innovation Canvas* will help the organization to understand the interrelationships of those key drivers, their specific relevance for the future development of the organization, and/or for the planned next digital innovation project. It will provide the management with a proven structure and a 'common language' within the organization for the digital transformation. The *Digital Innovation Canvas* will help prioritize the digital innovation ideas and projects.

Business advisors will support manufacturing SMEs and introduce the process, as well as the *Digital Innovation Canvas* and the related tools as presented in Chapter 5. The following steps (see Figure 6) are recommended to use the DIPG with the *Digital Innovation Canvas* and its related tools:

- **Vision workshop:** The SME management will develop/review the organization's digitalization vision. This will create a common understanding of the management team's level of ambition to embrace digital innovation for future sustainable growth. Depending

FIGURE 6

STEPS TO DEVELOP AND IMPLEMENT THE DIGITAL INNOVATION CANVAS.



Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

on the size of the management team and the level of expertise in developing a vision, this workshop might be scheduled for half-a-day to one day. It should be well prepared and facilitated by the business advisor. This workshop is usually the initiation of an internal process to develop and refine the SME's digitalization vision.

Expected benefit: A commonly agreed digitalization vision is achieved as a guideline for the digital innovation process of the SME.

- **Introduction of the *Digital Innovation Canvas*:** The business advisor will explain to the management team

  - the main objective of completing the *Digital Innovation Canvas*, i.e., the development of a commonly agreed digital innovation roadmap ready for implementation;

  - the key drivers included in the *Digital Innovation Canvas*; and

  - how to use the canvas to trigger the digital innovation process for the organization.

  The canvas may be used as a first step for a specific digital innovation project derived from the digitalization vision (preferred option), or straightaway for developing the digital innovation roadmap for the organization. Each management team member is asked to individually fill up the *Digital Innovation Canvas* (ideally using DIN A1 templates)

according to the agreed scope (canvas for a digital innovation project or for the digital innovation process for the entire organization). The introduction of the *Digital Innovation Canvas* may be scheduled directly after the vision workshop and will last about two hours.

Expected benefit: A clear understanding of the structure and how to use the canvas for developing ideas for the digital innovation process is gained.

- **Individual reflection on the *Digital Innovation Canvas*:** Each member of the management team will fill in the *Digital Innovation Canvas* according to his/her best knowledge (using post-it notes). The individual reflection should be thorough yet efficient. It creates a multi-stakeholder view on digital innovation gaps and opportunities (estimated time is two to three hours)

  Important note: The completion of the *Digital Innovation Canvas* has to reflect the SME's very specific situation and requirements. The completed *Digital Innovation Canvas* should provide a clear rationale for the defined digital innovation process and related digital innovation projects. Each *Digital Innovation Canvas* is unique for each company. The discussion of the *Digital Innovation Canvas*'s key elements will trigger ideas for digital innovation projects or for the digital innovation process. These ideas should be captured to be further detailed and structured in the digital innovation roadmap.

  Expected benefit: The management will gain views on digital innovation from different management perspectives, and individual learning experience on how to use the canvas for future discussions on strategic development toward a digital innovation organization. Gaps and opportunities for digital innovation are identified by each member of the management team.

- ***Digital Innovation Canvas* workshop:** During a one-day workshop, all individually developed canvasses will be discussed and consolidated, facilitated by the business advisor. Key success factors are:

  - focus on the key stakeholders' demands and needs relevant for the SME;
  - relevant technologies and non-digital innovation enablers, such as skill levels in the organization, financial resources, etc.;
  - focus on the SME's digitalization vision, innovation capabilities, strengths to exploit digital innovation opportunities, and risk appetite;
  - identifying the optimal combination of the SME's strengths, advanced technologies to meet current and emerging customer needs, and business impact of the suggested actions;
  - clear understanding of key performance indicators (KPIs) and the expected business impact of implementing the proposed digital innovation project(s) and/or the digital innovation process; and
  - taking a stepwise approach defined in the digital innovation roadmap (modularization of the digital transformation) that allows experience gain within the SME to develop confidence in mastering the digital innovation process.

The consolidated version of the *Digital Innovation Canvas* will create the basis to define, prioritize, and agree upon the activities to further develop the digital innovation activities The estimated time will involve a one-day workshop followed by one to two days to consolidate all inputs.

Expected benefit: It will provide a common understanding of the key opportunities/ benefits/business impact of the digital innovation process of specific digital innovation projects with prioritization of the key opportunities closing the identified gaps.

- **Developing the roadmap for digital innovation:** The collected key opportunities are prioritized by their business impact and ease of implementation. The high-priority opportunities will be detailed in separate workshops and then consolidated in the form of a common roadmap indicating the KPIs, timelines, milestones, deliverables, responsibilities, costs, and expected benefits.

  The estimated time is half a day, which could also be part of the consolidation of all inputs from the *Digital Innovation Canvas* workshop.

  Expected benefit: Clear digital innovation roadmap to monitor the development and implementation progress of the high priority digital innovation projects, or of the digital innovation process to benefit from digital innovation opportunities

- **Monitoring the implementation of the digital innovation roadmap:** The milestones and deliverables as indicated in the roadmap will be evaluated by completeness, quality, adoption within the organization, the business impact achieved, and other KPIs as defined in the roadmap. In case of unforeseen roadblocks, counter measures should be taken.

  The estimated time will depend on the defined actions within the roadmap.

  Expected benefit: It enables effective risk management and on-time understanding of the innovation project's progress and realization of the business impact, while capturing the benefits of digital innovation, lessons learned, and enhancing of the organization's digital innovation skills.

With this approach, managers of manufacturing SMEs will gain applicable knowledge right from the first interaction. They will get access to effective management tools to drive the digital innovation process within their respective organizations.

4. RECOMMENDATION FOR USERS

The main user groups of the DIPG are business advisors, consultants, and managers of SMEs who have sufficient understanding of the situation of manufacturing SMEs. Business advisors and consultants should also have a good understanding of digital technologies and their application in manufacturing companies. Furthermore, experience in advising manufacturing SMEs in their digital innovation process is essential. The business advisors and consultants should be able to illustrate the key drivers for digital innovation (as shown in the *Digital Innovation Canvas*) with relevant best-practice examples. They should have a clear understanding of business administration, innovation management, transformation process, and importance of business impact and value creation for the SME during each step of their support. They should be able to engage the SME management and organization in the learning process and motivate them to take this digital innovation process as a unique opportunity to gain both in terms of competitiveness as well as in digital innovation management skills.

Business advisors and managers are encouraged to use the *Digital Innovation Canvas* and the supporting tools and templates that are presented in the sections below to stimulate creativity and learning experience. As the test of the digital innovation process with the *Digital Innovation Canvas* has shown, this approach delivers concrete benefits during each of the steps described in the section above. Complementary tools and templates may evolve during the implementation of the digital innovation process. These tools and templates should be available to the SME in a digital format. However, practical experience has shown that during workshops, hard copies of some of the templates increase the effectiveness and efficiency during the discussions within teams.

Business advisors and SME managers are encouraged to develop virtual networks/digital platforms for 'digital innovation experts' within their countries to share experience, best practices, and effective tools and approaches, thus creating innovative ways toward skill development for digital innovation in manufacturing SMEs.

Other key stakeholders in the digital innovation ecosystem will benefit from using the *"Digital Innovation Process Guide: Handbook for Manufacturing SMEs."* By sharing case examples presented here, trade associations can increase their members' awareness of, and skills in digital innovation and digital transformation. Policy makers can increase the impact of their digital innovation policies by integrating the development and implementation of the *Digital Innovation Canvas* as a requirement for gaining public support. Thus, the support reaches the manufacturing SMEs that are committed to transform their businesses into digital innovation organizations. In a similar way, investors can enhance the return on their investment when the SMEs' management are encouraged to lay a clear focus on the digital innovation opportunities that emerged from the use of the *Digital Innovation Canvas* and the related transformation processes. Service providers can serve manufacturing SMEs more effectively based on the results of the *Digital Innovation Canvas*. They can adjust their service offerings to the specific level of digital innovation proficiency of the SME clients. Academia can train students in digital innovation in manufacturing not only in theory

but also in practice. They can ask the students to support a manufacturing SME in completing the *Digital Innovation Canvas* and document the results from this experience of working with SME managers. Based on these cases, research can be performed on typical challenges SMEs face when driving their digital transformation programs.

This multi-stakeholder approach also increases the awareness of digital innovation and its business impact on manufacturing SMEs. When applied in practice, it will offer valuable feedback to SMEs and to all other actors in the digital innovation ecosystem. The practical use of the DIPG with the *Digital Innovation Canvas* will be illustrated in the sections below through concrete process steps, tools, and templates.

5. TOOLS AND TEMPLATES

BUILDING ON LESSONS LEARNED DURING THE VARIOUS PHASES OF THE CONCEPTUAL MODEL

The following sections provide guidance for practitioners within manufacturing SMEs as well as for business advisors supporting SMEs in implementing the digital innovation process. They also offer insights into key success factors for other key stakeholders of the digital innovation ecosystem. The tools and templates presented for the various phases, from 'awareness creation' to 'intervention,' 'transformation,' and 'feedback' here are meant to

- create awareness of digital innovation benefits;
- stimulate and facilitate the digital innovation process development in SMEs; and
- develop digital innovation skills within all key stakeholders in the digital innovation ecosystem.

The DIPG's tools and templates presented in the following sections have to be adapted to the SMEs' businesses (B2B or B2C), the industry, the level of digital innovation proficiency already achieved by the SMEs, and their value networks. The examples in the following sections are mainly from SME contexts to stimulate the discussion within the SMEs in developing their digital innovations. They are neither exhaustive nor universally applicable.

The examples provided here are complemented by practical experience during the testing of the DIPG with around 100 manufacturing SMEs in India, Singapore, the ROC, and Vietnam. They are structured by the elements of the Conceptual Model (see section 3.2) and the *Digital Innovation Canvas* (see section 3.4) for practitioners and business advisors experienced in manufacturing industries, innovation management, digital innovation, and transformation of SMEs. Each of the following sections is divided into

- objectives of the process step (see section 3.2);
- focus;
- brief description of activities; and
- complementary tools and templates.

5.1. Leveraging the Current Level of Digitalization

The current level of digitalization in SMEs relates to the general degree of digitalization in the industry sector(s) relevant for the manufacturing SME that the practitioner is supporting. Gaining an overview of the current level of digitalization on the company level as well on the level of the digital innovation ecosystem is the basis for effective support measures. The business advisors play

an important role in enhancing the awareness for digitalization both in manufacturing SMEs and the ecosystem.

5.1.1. Objectives of the Process Step

- Understanding the business potential of further digitalization for the manufacturing SMEs and the competitive threats from neglecting digital innovation. These may affect the manufacturing SMEs' competitiveness and the regions' economic development (see Figure 7).

- Creating the need for action on the level of industry associations, policy makers, digital innovation hubs, investors, academia (education and research), developers/providers of (vocational) training programs, and the manufacturing SMEs themselves. The prerequisite is a clear understanding of the key players in the digital innovation ecosystem and their role in supporting SMEs (see Figures 9 and 10).

- Providing media with relevant data and information on the strengths, weaknesses, opportunities, and threats of digitalization in manufacturing SMEs and within their value networks (see Figures 7 and 8).

- Initiating actions on national, regional, sectorial, and company levels to identify priorities in the development of the digital innovation process in manufacturing SMEs; defining actions to address these priorities; and defining and implementing interventions required to make progress.

5.1.2. Focus of Leveraging the Current Level of Digitalization

Here the main focus is on mobilizing the key actors in the digital innovation ecosystem, including media, to highlight the benefits of digital innovation in manufacturing SMEs. This step should also help in mobilizing the manufacturing SMEs to initiate or further develop their digital innovation processes.

5.1.3. Brief Description of Activities

- Collect data on the business potential of digital innovation in manufacturing SMEs from selected industries/case examples either in your country or in other countries.

- Define which actions/roles various key actors in the digital innovation ecosystem can take to support manufacturing SMEs in driving their digital innovation process, and how to convince them to take actions.

- Highlight the benefits for each actor in engaging in the promotion of digital innovation in manufacturing SMEs (see Figure 11 and 12).

- Contact the key actors in the digital innovation ecosystem where you would like to drive the implementation of the digital innovation process in SMEs and mobilize them to increase the SMEs' awareness of digital innovation and its benefits for the companies, the economic development, and the people in the region (see Figure 13 and 14).

- Publish your insights/recommendations/proposals on how to increase the level of digitalization, especially in manufacturing SMEs, on your website, jointly with media partners in relevant online, and offline media.

- Present your insights in (virtual) workshops, conferences, and meetings with the key actors in the digital innovation ecosystem, especially with representatives of ministries, trade associations, chambers of commerce, and other multipliers in your country/region.

5.1.4. Complementary Tools and Templates

The following tools and templates are designed to support both the actors in the digital innovation ecosystem, i.e., the practitioners and the business advisors. They are not exhaustive. Depending on the current level of digitalization in the manufacturing industry, the SME's specific situation and their level of digitalization, complementary tools and templates might be necessary.

FIGURE 7

TEMPLATE 1.1 FOR CASE EXAMPLES HIGHLIGHTING BUSINESS POTENTIAL OF DIGITAL INNOVATION.

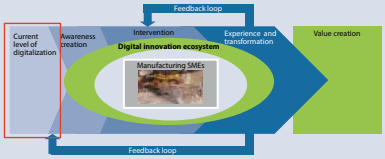


Figure 2

Template

1.1 Case examples highlighting the business potential of digital innovation in manufacturing SMEs
Examples from _____:

- …

Basis of improvements (selected examples):
- …

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 8

GERMAN MANUFACTURING SME's CASE EXAMPLE BASED ON TEMPLATE 1.1.

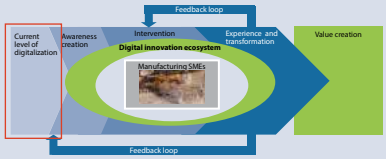


Figure 2

Example

1.1 Case examples highlighting the business potential of digital innovation in manufacturing SMEs
Examples from German manufacturing SMEs adopting I4.0 approaches:

- Increase of productivity: between 18% and 55%
- Reduction of manufacturing cost: between –6% and –20%
- Reduction of downtime: between –30% and –50%
- Reduction of ramp-up cost: between –40% and –50%
- Reduction of time to market: between –20% and –50%

Basis of improvements (selected examples):
- Robot-assisted manufacturing
- Tele-maintenance
- Connected production that enables automated setup, digitalized/connected material flow, and material control

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 9

TEMPLATE 1.2 FOR MAP OF KEY PLAYERS IN THE DIGITAL INNOVATION ECOSYSTEM.

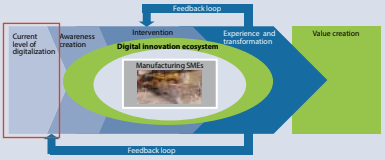


Figure 2

Template

1.2 Map of key actors in the digital innovation ecosystem, how to reach them, and how to address them.

Name of the digital innovation ecosystem: _____			
Key actors in the digital ecosystem	Key actors' specific role in digital innovation support for manufacturing SMEs in the digital innovation ecosystem	Key actors' specific interest in the level of digitization in the ecosystem	Comments/ notes/actions

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 10

EXAMPLE MAP OF KEY PLAYERS BASED ON TEMPLATE 1.2.

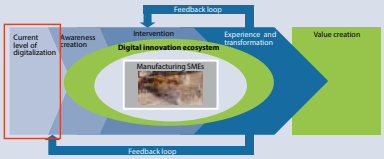


Figure 2

Example

1.2 Map of key actors in the digital innovation ecosystem, how to reach them, and how to address them.

Name of the digital innovation ecosystem: *Digital Saxony*			
Key actors in the digital ecosystem	Key actors' specific role in digital innovation support for manufacturing SMEs in the digital innovation ecosystem	Key actors' specific interest in the level of digitization in the ecosystem	Comments/ notes/actions
• Digital Innovation Hub	• Introducing IoT solutions to the companies in the region	• Supporting SMEs in gaining competitiveness by continued digitalization	Collaborate with them in support of SMEs
• Technical University Dresden	• Research on advanced digital technologies	• Contributing to highly skilled labor force • Testing the research results in an SME context	Organize 'applied advanced technology' workshops with SMEs

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 11

TEMPLATE 1.3 FOR HIGHLIGHTING BENEFITS FOR KEY ACTORS IN THE DIGITAL INNOVATION ECOSYSTEM.

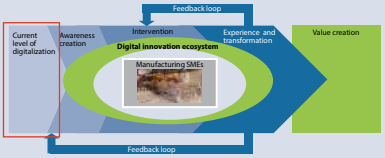


Figure 2

Template

1.3 Benefits for key actors in the digital innovation ecosystem.

Name of the digital innovation ecosystem: _____			
Key actors in the digital ecosystem	Key actors' specific interest in the level of digitization in the ecosystem	Key actors' specific benefits from supporting manufacturing SMEs in their digital innovation process	Comments/ notes/actions

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 12

EXAMPLE OF BENEFITS FOR KEY ACTORS IN THE DIGITAL INNOVATION ECOSYSTEM BASED ON TEMPLATE 1.3.

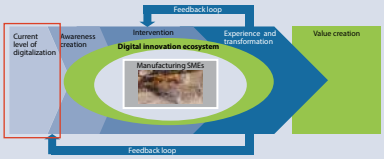


Figure 2

Example

1.3 Benefits for key actors in the digital innovation ecosystem.

Name of the digital innovation ecosystem: *Digital Saxony*			
Key actors in the digital ecosystem	Key actors' specific interest in the level of digitization in the ecosystem	Key actors' specific benefits from supporting manufacturing SMEs in their digital innovation process	Comments/ notes/actions
• Digital Innovation Hub	• Providing IoT solutions to the companies in the region	• Getting access to SMEs and expanding client basis for further IoT support services	Focus on growth of SME's client network

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 13

TEMPLATE 1.4 FOR ACTION PLAN TO IDENTIFY PRIORITIES FOR DEVELOPMENT OF THE DIGITAL INNOVATION PROCESS AT VARIOUS LEVELS.

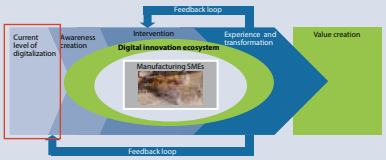


Figure 2

Template

1.4 Developing an action plan to identify priorities for the development of the digital innovation process on national, regional, sectorial, and company levels.

Actions	Benefit of action	Responsibility	Timeline	Comment

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 14

EXAMPLE ACTION PLAN TO IDENTIFY PRIORITIES BASED ON TEMPLATE 1.4.

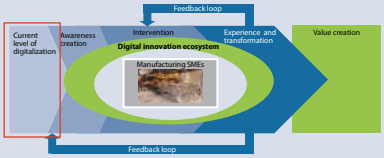


Figure 2

Example

1.4 Developing an action plan to identify priorities for the development of the digital innovation process on national, regional, sectorial, and company levels.

Actions	Benefit of action	Responsibility	Timeline	Comment
• Define current level of digitalization in manufacturing SMEs	• Understand the gap to best practice	• National Ministry of Trade	• Completed by MM/YYYY	Check statistical relevance of results
• Identify gaps in engineering skills accessible to manufacturing SMEs	• Define training relevant for future labor force in manufacturing SMEs	• Ministry of Education • Academic institutions • Technical education centers	• Completed by MM/YYYY	Address sector-specific needs

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

5.2. Creating Awareness for the Need to Develop the Digital Innovation Process

Awareness around the need to develop the digital innovation process in manufacturing SMEs will facilitate the recruitment of SMEs to engage in digital innovation as a powerful means to respond to customer requirements, competitive pressure, and unexpected changes in the value chains, and to achieve internal growth objectives.

5.2.1. Objectives of the Process Step

- Identify manufacturing SMEs that are interested in developing their digital innovation process, using Table 1.

- Convince the SME management of the benefits of developing their digital innovation process. Highlight the benefits of an enhanced digital innovation process (productivity gains, enhanced innovation capabilities, increased competitiveness, increased attractiveness as employer, etc.); provide compelling case examples from SMEs within the same industry (see also Chapter 9); and also illustrate threats emerging from underestimating the importance of digital innovation (see Table 2).

5.2.2. Focus of the Process Step

- Create confidence among the SME management that the development of the digital innovation process is doable and manageable with a stepwise approach as well as important for the future sustainable development of the company.

- Provide a vision of the SME's potential future manufacturing through story telling (see Table 3).

5.2.3. Brief Description of Activities

- Organize workshops for SMEs to provide general information on the benefits and process steps to develop the digital innovation process. Systems integrators and other technical experts might complement the workshop with their inputs (see Table 4).

- Arrange meeting with the SME management to discuss the benefits, actions/ potential steps, investments, risks, etc. of a digital innovation process development project more in detail (see Table 5).

- Inform and invite to best practice examples and training programs on digital innovation

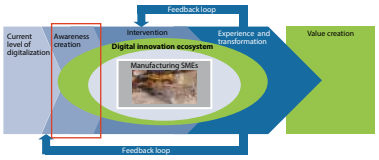
- Follow-up on specific digital innovation issues that the SME management would like to discuss and further explore (see Table 6).

5.2.4. Complementary Tools and Templates

The following tools and templates are designed to support both the practitioners and the business advisors. Other actors in the digital innovation ecosystem will also benefit from these tools and templates. They are not exhaustive. Depending on the current level of awareness for digital innovation in SMEs, complementary tools and templates might be necessary.

TABLE 1

SELECTION CRITERIA TO IDENTIFY SMEs INTERESTED IN DEVELOPING DIGITAL INNOVATION PROCESS.



Criterion	Comment	Ranking of criterion	List of SMEs complying with criterion
Industry sector in which the manufacturing SME is active	Automotive and electro/ electronic have higher level of digitalization than others		
International activities of the manufacturing SME	The more international the SME's business is, the more competitive pressure might exist		
Growth of the manufacturing SME	High-growth SMEs are usually better managed than 20-year-old SMEs that still have only 20 or less employees		
Awards won by the manufacturing SME	SMEs that participate in competitions are usually more ambitious		
SME's participation in training on digitalization	Illustrates interest in the topic		
Received funding for, say, digitalization	Illustrates interest in their digitalization		
Recommendation from client/business partner	Shows interest in the topic		
…			

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

TABLE 2

LIST OF BENEFITS FROM IMPROVED DIGITAL INNOVATION PROCESS.

Benefit	Case example	Improvement area	Success factors/ comments
Increased flexibility	Manufacturing SME introduced digitalization and automation	Production, development, logistics, after sales	Commitment of top management
Reduced downtime and emergency repair	Manufacturing SME introduced predictive maintenance based on data on temperature and vibration	Production	Introduction of sensors
Reduced sick days	Manufacturing SME introduced robots in manufacturing	Ergonomics	Training in interaction with robots
Differentiated product value in the market	Implemented big data and analytics	Product development	Incorporate data analytics into decision-making process
Increased customer satisfaction	Introduced AI and big data analytics	Sales and marketing	Openness for agile and efficient management approaches

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Benefit	Case example	Improvement area	Success factors/ comments
Reduced time to market	Introduced IoT to increase efficiency and save time	Production	Coherent and transparent information for efficient communications
Improved quality assurance	Introduced collaborative robots	Ergonomics	Training on how to work alongside robots
Increased sales	Digital marketing	Sales	Digital talent and teamwork collaboration
Increased productivity	Introduced collaborative robot	Production	Employees' commitment
Increased productivity	Introduced sensors and image recognition technology	Production	Introduction of sensors, training on problem-solving protocol
Increased efficiency	Introduced cloud ERP system	Production and sales	Training on ERP application
Increased product quality and customization	Advanced manufacturing cloud of things-AVM	Production	Training in smart manufacturing process
Prediction of market trend and demand	Implemented big data and analytics	Marketing and sales	Commitment at managerial level
Prediction of customer demands and behaviors	Automated pedestrian detection, count, and analysis system	Sales and allocated manpower resources efficiently	Use the data correctly in decision-making process
Reduction of design and development time by 30% and development issues by 40%	SME introduced virtual testing, PLM, digital library of FMEA, computer aided design (CAD), standards, sample approval and pilot approval documents SMEs planning for digitalization of advanced product quality planning process	Design and development	• Customer requirement • CEO-led transformation • Real-time simulations and feedback systems • Centralized document control
Reduction of line rejection by 35% and process capability CP-CPK >1.67	SME introduced real-time monitoring and control of product and process parameters, i.e., printing speed, pressure, auto cleaning of stencil, solder paste height and volume, real time statistical process control, traceability of product and process parameters, and maintenance systems. Furthermore, the SME is planning for the online software for process performance (PP) and process performance index and performance test rigs integrated with sensors and analytics software	Production PCB printing Soldering Automated vision inspection	• CEO led transformation • Benchmarking best practices • Regular training and development of local in-house experts

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Benefit	Case example	Improvement area	Success factors/ comments
Zero recall risk	SME introduced traceability of child parts, raw materials, process parameters, automatic program changeover and bill of material (BOM) verification, vision system for part miss and shift, process interlocking with the previous proven process cycle, rea-time monitoring, and control of product and process parameters.	Production, incoming inspection, quality gates, and final inspection	• CEO-led transformation • Customer requirement • Regulatory requirements of government
100% adherence to the delivery schedules	SME introduced SAP and enterprise resource planning (ERP) and warehouse management system integrated with ERP and real-time monitoring of schedules	Warehouse, supply chain management, logistic, and customer support	• CEO-led transformation • Customer requirement • Business continuity due to supply chain disruptions in lockdown
Planning for 97% of the automated operations by robotics	SME introduced robotics in the welding process, inspection of parts, gauging, and corrections Furthermore, planning is being done for the automated guided vehicles (AGV) compatible shop floor	Production	• CEO-led transformation • Need for zero defects • Business continuity due to manpower issues in COVID-19
Zero defect outflow and Increased customer satisfaction	SME introduced 100% check of the performance parameters, automatic 'OK' decision, real-time statistical process control, traceability, and process interlocking with the previous proven process cycle	Quality checks	• Customer requirement for zero defects • Competitive pressures

Source: Eva Diedrichs desk research, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

TABLE 3

OUTLINE FOR DEVELOPING A VISION OF SMEs' FUTURE MANUFACTURING.

Outline for story telling
• Set realistic time horizon to place your story in the future. • Define 'personas' that will describe the future as their current present, for example, head of production, technician, head of development, head of sales and marketing, customer, supplier, etc. • Let the personas explain, how their business 'today' works and how they managed to reach this level of digitization, automation, or connectivity. Focus should be on the triggers for the digital innovation, the success factors, and how the SME managed to overcome the roadblocks. • Engage the SME management in a discussion on how they see the future development of their company. • Document the SME management's vision and potential changes. • Share the results of the story telling exercise with the SME management.

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

TABLE 4

POTENTIAL AGENDA FOR WORKSHOPS TO PROVIDE GENERAL INFORMATION TO SMEs FOR DEVELOPING THE DIGITAL INNOVATION PROCESS.

Time in minutes (indicative)	Topic	Who
15	Welcome and introduction of participants	Facilitator/participants
5–10	Expectations of the participants regarding the workshop	Participants
10	Objectives of the workshop	Facilitator
10	Definition of the digital innovation process	Facilitator
30	Examples of improvements of the digital innovation process, including achieved benefits and success factors	Facilitator
25	Q&A related to the presented case examples and how they could be adopted in the participants' organizations	Participants
15	Discussion on potential opportunities and gaps in the participating SMEs' digital innovation process and the next steps	Participants/facilitator
5	Summary of workshop results and end of meeting	Facilitator

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

TABLE 5

POTENTIAL AGENDA FOR MEETING WITH THE SME MANAGEMENT TO DISCUSS THE BENEFITS, ACTIONS, INVESTMENTS, RISKS, ETC. OF A DIGITAL INNOVATION PROCESS DEVELOPMENT PROJECT.

Time in minutes (indicative)	Topic	Who
10	Welcome and introduction of participants	If the workshop is conducted at the SME's premises, then the SME management; otherwise, the national expert/business advisor
10	Workshop participants' expected outcome of the meeting	SME management or national expert/ business advisor
15	Current level of digitization and digitalization in the SME organization	SME management
15	Key areas for further digitization and digitalization	SME management
15	Relevant case examples of digital innovation and their business impact	National expert/business advisor
20	Introduction of the *Digital Innovation Canvas* as approach to identify the most promising areas to reach the next level in the digital innovation process	National expert/business advisor
15	Q&A related to the *Digital Innovation Canvas*	All
10	Definition and agreement on next steps, timelines and responsibilities	All
5	Wrap up and closing of the meeting	If the workshop is at the SME's premises, then the SME management; otherwise, the national expert/business advisor

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

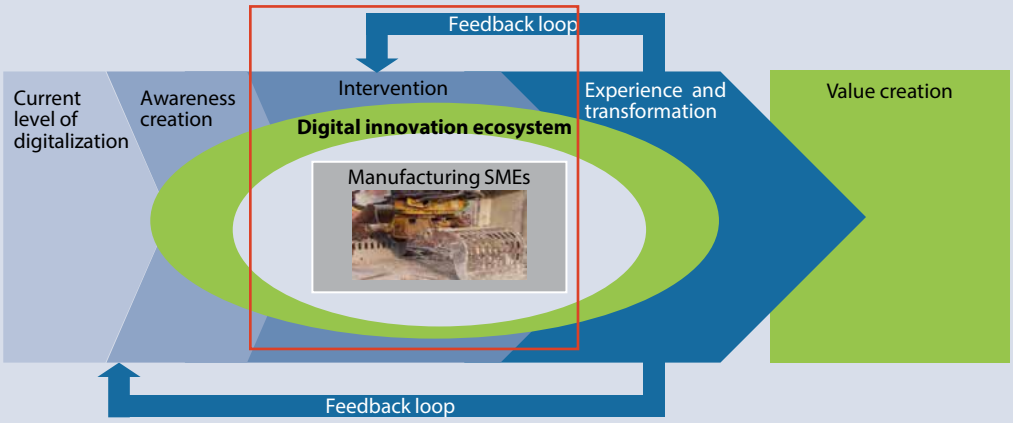
5.3. Intervention to Develop the Digital Innovation Process at Manufacturing SMEs

This section focusses on the direct intervention at manufacturing SMEs. Interventions at other stakeholders to develop the digital innovation process will be briefly addressed at the end of this section.

The digitalization vision and the current challenges and opportunities for the manufacturing SMEs form the starting point for the development of the digital innovation process at the SMEs.

FIGURE 15

CONCEPTUAL FRAMEWORK WITH FOCUS ON INTERVENTION.



Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

5.3.1. Objectives of the Process Step

- Develop and commit the SME to its digitalization vision.
- Support the SME in developing its *Digital Innovation Canvas*, and in developing and implementing a roadmap for establishing its digital innovation process.
- Clearly define and quantify to the degree possible the expected impact from developing and implementing the digital innovation roadmap.

5.3.2. Focus of the Process Step

- Engage the SME management and organization in the digital innovation process.
- Concentrate on feasibility and business impact of interventions.
- Develop a stepwise digital innovation roadmap as the basis for the digital innovation process.
- Define measurable key performance indicators for each of the steps.

5.3.3. Brief Description of Activities

- Develop digitalization vision for SME (vision workshop, if required virtually). At this stage, the *Digital Innovation Canvas* might already be introduced (see Template in Section 3.3).
- Introduce the *Digital Innovation Canvas* (through workshop, if required virtually). This may include a first discussion of the key areas that are represented. It may also lead to first ideas that might be relevant for the development of the SME's specific *Digital Innovation Canvas* (see Section 3.4).
- Draw individual reflection on the *Digital Innovation Canvas* by the SME management team members. Gain support of the SME management in adopting/developing their *Digital Innovation Canvas* (e.g., via phone calls).

- Conduct *Digital Innovation Canvas* workshop to identify opportunities and benefits of the digital innovation process and of specific digital innovation projects to close identified gaps.

- Develop the roadmap for digital innovation by consolidating the actions resulting from the completed *Digital Innovation Canvas*. This leads to

    - prioritized activities;

    - an evaluation of the required investment, other resources, and the expected business impact;

    - defined roles, responsibilities, and timelines for the implementation of the digital innovation roadmap; and

    - defined milestones, KPIs, deliverables, and risk mitigation approaches.

5.3.4. Complementary Tools and Templates

The following tools and templates are designed to support both the practitioners and business advisors. They are not exhaustive. Depending on the current level of digitalization in the manufacturing industry, the SME's specific situation and its level of digitalization complementary tools and templates might be necessary.

5.3.4.1. Developing the SMEs' Digitalization Vision

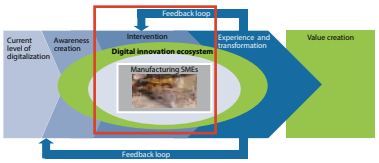


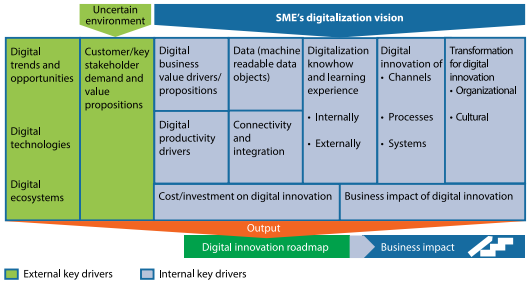
TABLE 6

KEY QUESTIONS TO BE ANSWERED WHEN DEVELOPING THE SME's DIGITALIZATION VISION.

- What is the company's overall vision?
- Is it
    - Linked to innovation and/or digitalization?
    - Understood and shared by all employees?
    - Broad enough to encompass a variety of perspectives?
    - Easy to communicate?
    - Inspiring and uplifting?
    - Concise and inclusive?
    - Action- or outcome-oriented?
- Does it
    - Guide management's thinking on strategic issues?
    - Help define performance standards?
    - Guide employee's decision-making?
    - Help establish a framework for ethical behavior?
    - Create closer linkages and better communication with customers, suppliers, and alliance partners?
    - Promote external support?
- What are the key drivers for digital innovation for the SME?
- What is the management's ambition for digital innovation?
- How urgent is digital innovation for the SME?
- Does the drafted digitalization vision comply with the criteria defined for the SME's overall vision (see above)?

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs; IMP^{3}ROVE [19].

5.3.4.2 Introducing the *Digital Innovation Canvas*



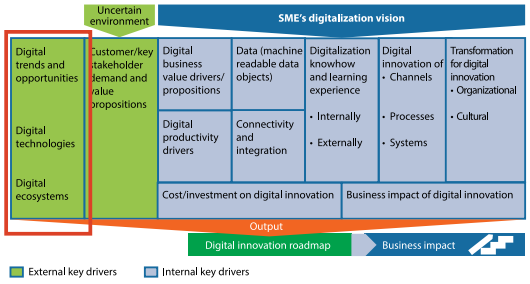
Each of the *Digital Innovation Canvas*'s (see Section 3.4) key areas and their interlinkages will be explained to the SME. Compelling examples (see also case examples in Chapter 9) related to the SME's industry and level of maturity in digital innovation will be provided. To make the most use of the *Digital Innovation Canvas*, the information and ideas for each of the sections provided in the *Digital Innovation Canvas* should be as specific and relevant as possible for the SME's current situation. During the introduction of the *Digital Innovation Canvas* to the SME management, first ideas on digital innovation may emerge and should be captured for input during the following workshop with the SME management.

It should be clearly stated that the starting point will be the current level of digitalization in the SME. Digital innovation is an ongoing process. The steps and speed in this process are defined by the SME's level of ambition and digitalization vision; the customer demand for digital innovations; the availability of advanced technology solutions suitable for SMEs; and the financial, human resource, and management capacities of the SME.

The output of the digital innovation process could be productivity gains from automation, smart products, or digital business models, e.g., subscription models similar to software as a service (SaaS), where machines are not sold but paid on the basis of their use by the customer. Digital innovation projects are successful when they lead to profitable growth of the SME either by increasing the customer base, sales, and revenues, and/or by reducing throughput time, material, labor, or energy, among others. There are examples where there have been significant improvements in SMEs through digital innovation in areas such as productivity, manufacturing cost, downtime of production, quality cost, ramp-up cost, and time to market.

In the following tables and templates, further details on each of the *Digital Innovation Canvas*' key areas and examples are provided. They are not exhaustive. Experience in different countries, industries and for different types of SMEs might lead to further value propositions.

Digital trends, opportunities, technologies, and ecosystems



Digital trends such as I4.0 with the demand for connectivity, interoperability, and real-time data, will create opportunities for SMEs to succeed in their markets provided they understand how best to invest in the required digital technologies such as cloud computing, smart machinery, sensors, 3D printing, etc. The challenge for SMEs is to identify solutions that will fulfill their needs while at the same time meet their budget requirements. SMEs that are at the beginning of their digital innovation journey might use low-budget technologies to become more technology savvy. This might help them to integrate step by step into the digital ecosystems that offer them new business opportunities.

Customer/key stakeholder demand and value propositions

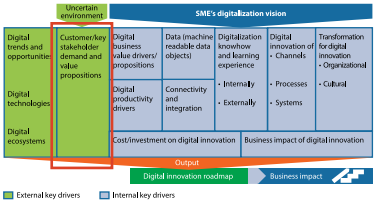


TABLE 7

EXAMPLES OF CUSTOMER/KEY STAKEHOLDER DEMANDS AND VALUE PROPOSITIONS.

Customer/Key stakeholder demand (examples)	Value propositions (examples)
On-demand production	99% just-in-time delivery
Flexibility	Short ramp-up times for change of products
Automated tracking of prices	Real-time transparency on prices
Automation of processes (e.g., the generation of bill of materials)	Increased processing quality
Transparency on stock and delivery times throughout the supply chain	Real-time information about stock, delivery time, and prices
Scalability of logistics systems	Management of end-to-end logistics processes
Synchronization throughout the supply chain to avoid rework and communication interruptions	Quality improvement
Traceability of products via unique component identification, e.g., for adaptive quality control	Identification of objects
Process capability (CP/CPK) of critical to quality and safety parameters >1.37	Capable processes with zero-defect outflow to customers
Faster corrective action preventive action (CAPA) on the software	Better agility and responsiveness
Online monitoring of productivity, loss analysis, and overall equipment effectiveness (OEE) on cloud	Improving productivity by recording equipment availability, stoppages with duration, production quantity, and rejection quantity to identify bottlenecks for analysis
Digitalization of quality planning documents (FMEA, control plan, work standards, pre delivery inspection reports, etc.)	Standardization of documents and records with faster retrieval
Digitalization of gauge calibration and measurement system analysis	Reliability of the measurement system in statistical and scientific way.
Shared supplier portal	Real-time monitoring and control for greater visibility into orders and inventory to deliver on customer promises, corrective and preventive actions, and alerts in real time
Paperless compliance management on audit cloud	100% adherence of audit plans and closures leading to risk mitigation Real-time monitoring of the product, process, and system audits and closures across multiple teams at multiple locations

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Customer/Key stakeholder demand (examples)	Value propositions (examples)
Cloud-based maintenance management system	100% adherence of preventive and daily maintenance schedules and real time monitoring and control
Shared Kaizen bank on cloud	Learning by sharing in real time
On-line PDI submission by suppliers	Real time monitoring and control along with standardization.

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs; Sanjiv Narula, National Expert, India.

Digital business value drivers/propositions

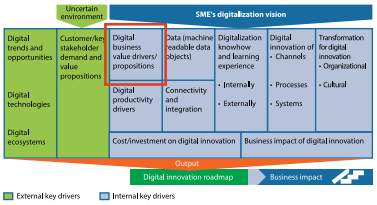

TABLE 8

EXAMPLES OF DIGITAL BUSINESS VALUE DRIVERS.

Successful digital business model
Established digital business platform
High digital integration into the supply chain of key customers and suppliers (connectivity), based on state-of-the-art digital solutions and systems (interoperability)
Strong cybersecurity measures
Superior skills and proven track record in digital innovation, such as successful commercialization of 'smart' products
Active collaboration with digital innovation hubs

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Digital productivity drivers

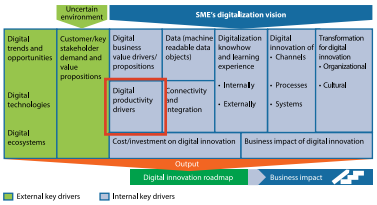

TABLE 9

EXAMPLES OF DIGITAL PRODUCTIVITY DRIVERS.

Level of systems integration internally and within the business partners (value networks)
Speed of systems integration
Effective use of digital systems by all employees
Time-to-market/time-to-profit for digital innovations
Collaboration speed and effectiveness with internal and external partners on digital innovation
Technologies such as machine-to-machine communication
Developing new digital value propositions from data analytics

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Data (machine readable data objects)

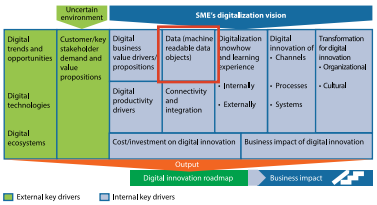

TABLE 10

EXAMPLES OF DATA MANAGEMENT (MACHINE READABLE DATA OBJECTS).

Digitization of information
Digital data collection and management
Coherence and uniformization of data
Visualization of data for better management of operations
Data analytics
Translating the results of data analytics into new digital offerings or productivity gains
Turning physical objects into digital products

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Connectivity and integration

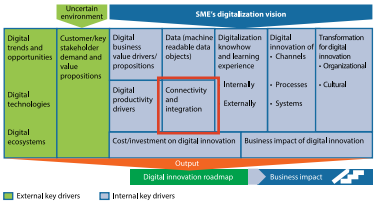

TABLE 11

EXAMPLES OF CONNECTIVITY AND INTEGRATION WITHIN AND ACROSS THE ORGANIZATION AND THE VALUE NETWORKS.

Systems integration and flexibility
Data integration
Process integration
Organizational integration
Interoperability
Coherence of data, systems, organizational units, and culture

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Digitalization knowhow and learning experience internally and externally

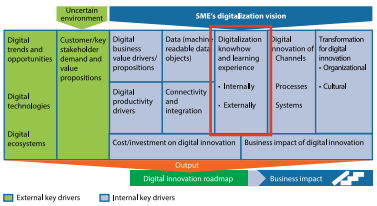

TABLE 12

EXAMPLES OF DIGITALIZATION KNOWHOW AND LEARNING EXPERIENCE INTERNALLY AND EXTERNALLY.

Implementation of ERP and/or other IT systems within the organization
Percentage of staff with direct access to personal computer
Number of IT experts with university degree/practical experience in software development, systems administration, and/or systems integration

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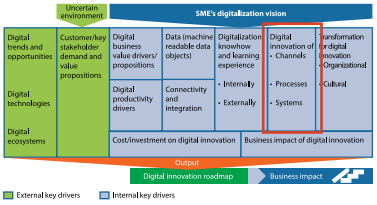
Use of advanced digital technologies in manufacturing
Experience in digitalization of physical products
Collaboration with external resources with digitalization knowhow
Support from supply chain partners in further integration
Support from the digital platform service providers such as Amazon, Alibaba, and Ebay

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Digital innovation of channels, processes, and systems:

TABLE 13

EXAMPLES OF DIGITAL INNOVATION OF CHANNELS, PROCESSES, AND SYSTEMS.



Channels
Online shop
Supplier platforms (crowd sourcing)
Social media
Blogs
Company websites
Processes
Trend analysis
Resource planning, prototyping/'digital twins'
Systems
Idea/knowledge management systems
Cyber-physical production systems (CPPS)
Manufacturing Execution System (MES)

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Transformation for digital innovation:

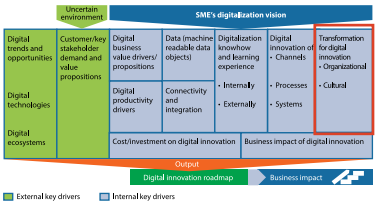


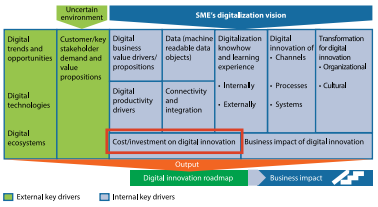
TABLE 14

EXAMPLES OF TRANSFORMATION FOR DIGITAL INNOVATION.

Transformation for digital innovation (selected examples)
Organizational
Shifting from functional to a process-oriented organization
Delegating responsibilities for faster decision making
Adopting agile management approaches
Cultural
Involving more key staff members from different functions and background in the innovation processes
Rewarding successful ideas for digital innovation (financial and especially nonfinancial rewards)
Shifting from financial incentives to more nonfinancial incentives for staff members

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Cost/investment for digital innovation



The SME should gain a detailed understanding of the cost and investment required for each digital innovation project that will help achieve its digitalization vision. Transparency will increase if the management has an understanding of the investment in

- new digital technologies;
- external support to integrate the new digital technologies;
- training cost to educate staff members in the new technologies (including training fees, travel cost, and labor cost); and
- system-related support and maintenance cost.

Other investments

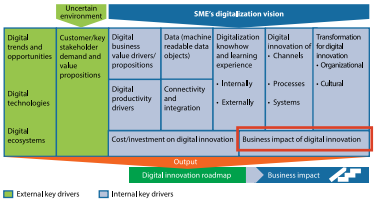
In a similar way, the cost for introducing a digital innovation has to be assessed, such as

- marketing and promotion of the value added achieved by the adoption of new technologies;

- cost of downtime in the production during the transfer from the current technologies/ processes to the new approach;
- cost of testing the new technologies/processes; and
- other costs.

Business impact of digital innovation

A simple test to evaluate the business impact from digital innovation lies in answering the question, "What if our key competitor will come up with this idea? Will this jeopardize the existence of our business?" Most digital innovation projects will have to be evaluated more in detail to prioritize them. The following criteria may be applied, among others:



- time to market;
- time to profit;
- return on investment;
- cost-saving potential, e.g., energy, material, and scrap reduction;
- retention/acquisition of long-term, high-value customers;
- increase in revenue and market share;
- compliance with customer/other stakeholder requirements, e.g., electronic VAT declaration;
- compliance with sustainability;
- improved position at the labor market (recruiting qualified candidates);
- meeting other key performance indicators as defined by the SME; and
- compensating (potential) loss of business due to upcoming new standards or governmental regulations.

5.3.4.3 Developing the Digital Innovation Roadmap

Starting with the development of the digital innovation roadmap builds the transition from the intervention phase to the transformation phase.

To prioritize the digital innovation ideas that emerged from completing the *Digital Innovation Canvas*, the matrix shown in Figure 17 can be helpful.

Ease of implementation relates to the effort required to implement the digital innovation idea/ project. Business impact includes the various benefits that the company will gain when implementing

the digital innovation idea/project. The allocation of all digital innovation project ideas within this matrix will help prioritize them in the digital roadmap for the SME. It will help to agree on priorities.

FIGURE 16

KEY STEPS IN DEVELOPING THE DIGITAL INNOVATION ROADMAP.

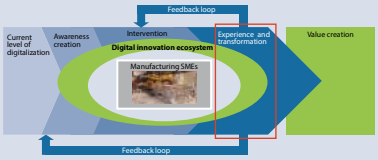
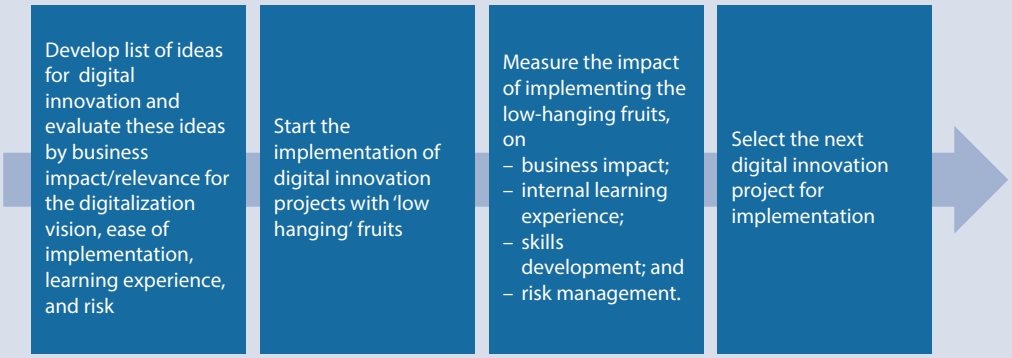


Figure 2

Examples

3.2 Developing the digital innovation roadmap.



Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 17

EASE OF IMPLEMENTATION/BUSINESS IMPACT MATRIX.

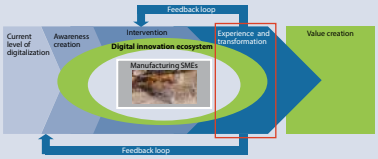
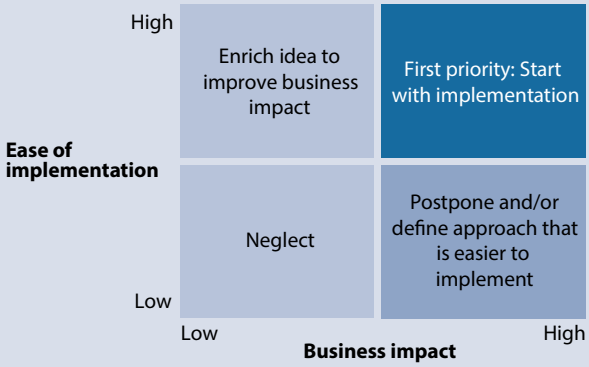


Figure 2

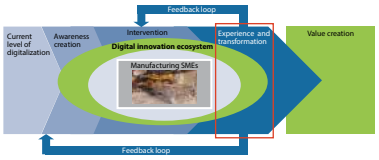
Examples

3.2 Developing the digital innovation roadmap.



Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

5.4. Experience and Transformation



SMEs engaging successfully in a digital innovation process will systematically leverage the experience gained from each digital innovation project to transform their organization including digitizing the data, digitalizing the processes, integrating the systems, adjusting the organizational structure and responsibilities suitable for a digitalized organization, and embedding digitalization and innovation in their culture.

5.4.1. Objectives of the Process Step

- Gain competitive advantage from developing the organization into a digital innovation champion as defined in the digitalization vision.
- Develop management approaches and systems to support an innovation culture that is able to leverage digital technologies.

5.4.2. Focus of the Process Step

- Engage the SME organization and other stakeholders of the ecosystem in the digital innovation projects. On the SME level, the entire organization will be involved. To create momentum, other stakeholders in the ecosystem will be engaged, e.g., IT providers, system integrators, and investors.
- Enable the team to drive digital innovation projects.

5.4.3. Brief Description of Activities

- Monitor the implementation of the roadmap based on the KPIs defined during the development of the digital innovation roadmap.
- Determine the business impact from completed digital innovation projects according to the predefined KPIs.
- Celebrate success to foster digital innovation and controlled risk-taking in the organization and share with relevant external stakeholders, e.g., the technology providers.
- Define actions to close identified gaps and define responsibilities for implementing these actions.
- Adjust organizational and management structures to the achieved level of digitalization, e.g., the new digital business models.
- Document and share lessons learned from the implementation of the digital innovations, especially success factors, KPIs, roadblocks, and risk management.
- Initiate next phase of digital innovation based on lessons learned from previous digital innovation project(s) by applying the *Digital Innovation Canvas* on a regular basis.
- Review progress in digital innovation. The ‘stages of excellence’ model might help to evaluate the progress and derive actions for further digital innovation.
- Review digitalization vision in due time.

5.4.4. Complementary Tools and Templates

The following tools and templates are designed to support both the practitioners and the business advisors. They are not exhaustive. Depending on the current level of digitalization in the manufacturing industry, the SME's specific situation, and its level of digitalization, complementary tools and templates might be necessary.

5.4.4.1. Stages of Excellence in Digital Innovation

TABLE 15

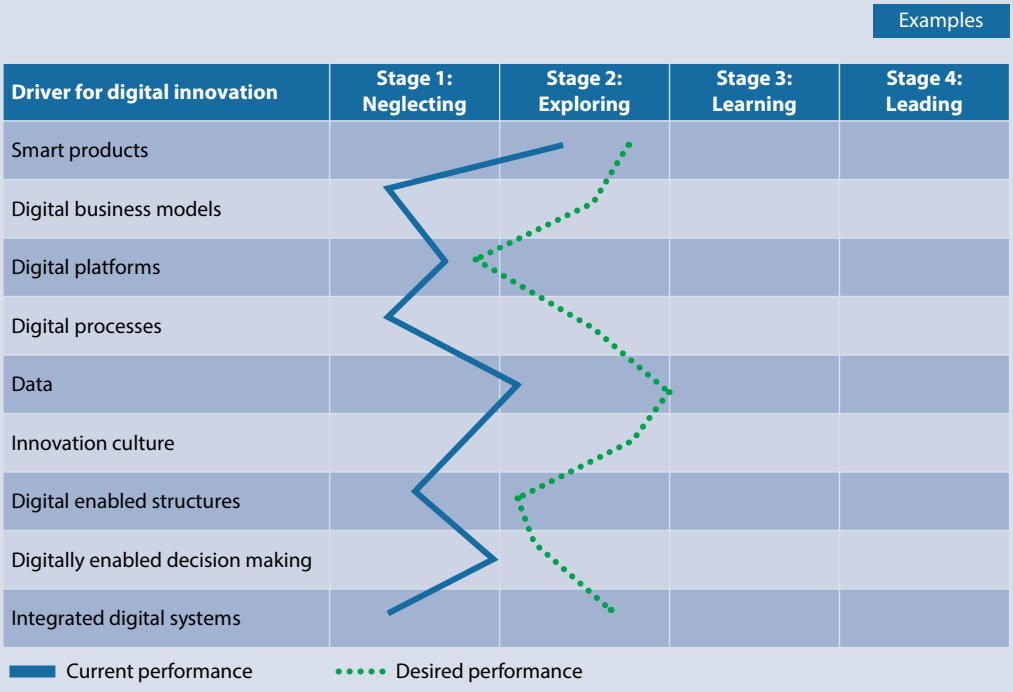
'STAGES OF EXCELLENCE' IN DIGITAL INNOVATION.

Driver for digital innovation (examples)	Stage 1: Neglecting	Stage 2: Exploring	Stage 3: Learning	Stage 4: Leading
Smart products				
Digital business models				
Digital platforms				
Digital processes				
Data				
Innovation culture				
Digitally enabled structures				
Digitally enabled decision making				
Integrated digital systems				

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 18

'STAGES OF EXCELLENCE' MODEL: EXAMPLE OF CURRENT AND DESIRED PERFORMANCE.

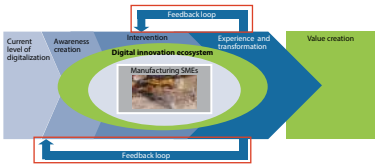


Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

5.5. Feedback Loop

Feedback on the development of the digital innovation process should be provided in more detail within the SME organization. Lessons learned from the digital innovation projects, including failures and successful approaches, should be shared within the project team as well as in a target group-specific manner with staff members. The purpose of regular feedback is the learning and skill development of each member in the organization. As appropriate, feedback on the overall level of digital innovation in SMEs can be provided in a consolidated manner to policy makers, trade associations, and investors for more educated decision making, as well as to media for creating awareness and mobilizing more SMEs to engage in digital innovation.

5.5.1. Objectives of the Process Step



- Mobilize and motivate the organization based on the achievements.
- Stimulate learning.
- Enhance proficiency in digital innovation.
- Understand the importance of communication in the digital innovation process.

5.5.2. Focus of the Process Step

- Provide target group focused feedback.
- Leverage successes to increase motivation while highlighting the need for further digital innovation.
- Create pride and motivation within the organization.

5.5.3. Brief Description of Activities

- Establish short feedback sessions as default in each team meeting with focus on lessons learned.
- Document progress and open opportunities, and share them with relevant stakeholders within the SME organization and with external stakeholders, as required and/or beneficial for the SME.
- Consolidate experience from digital innovation support to SMEs and share in sanitized form with policy makers, media, and academia.
- Optional: Organize ‘postmortem’ meetings to learn from failure. These can be highly educative, though much depends on the cultural context.

5.5.4. Complementary Tools and Templates to Capture Key Issues During Internal Feedback on the Digital Innovation Project

The issues listed in Table 16 are examples to choose from. The list is not exhaustive.

TABLE 16

QUESTIONNAIRE FOR INTERNAL FEEDBACK AFTER THE COMPLETION OF A DIGITAL INNOVATION PROJECT.

Key issues to be considered for internal feedback	1 Fully agree	2 Agree	3 Do not agree	If '3' please provide recommendation	Not applicable
The digital innovation project's objectives were very well communicated					
The digital innovation project's objectives were very well understood by all project team members					
The digital innovation project's objectives were in line with the company's digitalization vision					
The digital innovation project's key steps were well structured					
Each step/task had clearly defined deliverables and milestones					
The digital innovation project always received sufficient support					
The digital innovation project always received full management attention					
The tasks within the digital innovation project were clearly assigned					
The responsibilities for the various tasks within the innovation project were clearly assigned					
During the digital innovation project, I received very valuable information on advanced technologies					
With the additional knowledge about advanced technologies, I can add value in my day-to-day job					
Running the digital innovation project in an agile mode taught me new project management skills					
Working with different colleagues during the digital innovation process helped me to gain insights into other functions					
The challenges we faced during the digital innovation project were always well managed					
During the digital innovation project, we were asked to focus on problem-solving rather than problem-seeking					

(Continued on next page)

(Continued from previous page)

Key issues to be considered for internal feedback	1 Fully agree	2 Agree	3 Do not agree	If '3' please provide recommendation	Not applicable
Working with the *Digital Innovation Canvas* helped me to understand the interdependencies between digital trends, technologies, demand, and our value propositions					
Collaborating with external parties on advanced technologies demonstrated opportunities for our company that we were not aware of					
The business impact that we wanted to achieve from the digital innovation project has been achieved					
With the digital innovation project, the way we collaborate internally has significantly improved					
It was very helpful that we were asked to think 'out of the box'					
The focus on the business case during the digital innovation project helped to put all the ideas for additional digital innovation projects on our digital innovation roadmap					
We have defined clear performance indicators to measure the success of this digital innovation project					
If milestones and performance indicators are not met, we have clear risk mitigation measures in place					
There have been clear responsibilities defined to monitor the business impact of the digital innovation project					

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

5.6. Actions by other Stakeholders to Support the Digital Innovation Process

Actions by and within other stakeholders of the digital innovation ecosystem will be targeted toward better support of manufacturing SMEs. This support could be based on digital innovations at those stakeholder organizations. Large enterprise customers of the manufacturing SMEs can apply the digital innovation process within their organizations to provide their SME suppliers with guidance on key technologies they are looking for, and future digitalization requirements. Academic and training institutions can use the digital innovation process and the *Digital Innovation Canvas* to develop better (digitally enabled) education programs addressing the needs of manufacturing SMEs.

Public funding organizations' understanding of digital innovation's impact on manufacturing SMEs will develop with their key staff members' participation in workshops with SMEs focusing on the development of digital innovation process and roadmap. The test of the DIPG and its related tools has been a powerful eye opener for members of trade associations and tech centers. Understanding the need for very well-educated business advisors knowledgeable in digital technologies and their implementation in SMEs led to the decision that training of business advisors is one of the key tasks of intermediaries and policy makers.

Intermediaries, such as trade associations and chambers of commerce can develop their digital programs highlighting best practices via distant interaction with their members, for example.

6. BENEFITS FOR SMEs FROM DIGITAL INNOVATION

SMEs are constrained by lack of time, money, and skills. Therefore, they need to understand the benefits of digital innovation and be convinced by the approach to start/continue implementing a digital innovation process within their organization. Experience from other SMEs also facilitates the initiation of a digital innovation project.

6.1. General Learnings from Introducing Digital Innovation Process to SMEs

Testing the *Digital Innovation Canvas* and the related processes provided the following insights:

- The majority of SMEs introduced to digital innovation based on the approach of the DIPG stated a high learning experience.

- The business advisor must come up with a high-level plan as a proposal for discussion with the SME. This discussion should answer the fundamental questions relating to how and where digitization is required to both efficiently and effectively maximize value added as perceived by the end customer while satisfying the requirements of all involved stakeholders. For example, low-cost cloud technologies were of huge interest of SMEs in India. They help SMEs to learn about best practices. Also, online software contributes to standardization of documents, formats, and processes as a driver for efficiency.

- Most SMEs are concerned about the return on the investment as it is highly unpredictable with potential risk of loss. However, the company has to be aware that the digital transformation process is a continuing long-term process. Setting a three-to-five years goal on the return on investment is more realistic. The option of doing nothing might be even more risky for the company.

- When a company adopts the digital technology, it has to develop its digital business ecosystem. This will be based on its digital platforms to facilitate a network for interactions among its suppliers, partners, and customers in order to provide added value to all its participants. A key factor for success here is, for example, how the business model for the product is designed that it creates value for all actors in the digital business ecosystem.

- Adopting technologies will increase visibility and improve efficiency for suppliers, logistics providers, and vendors. However, during the digital innovation process, the company has to come up with a plan to balance between new technologies and established ones. For example, during the transition phase, it has to implement a mechanism to deal with the lack of traceability of parts supplied by third parties for better coordination.

- Digital innovation raises the question about cybersecurity. In manufacturing, sensor data are used to monitor and analyze the efficiency of machines to optimize the operations and

to provide after-sale services, including preventive maintenance. Yet, these developments are accompanied by digital security and privacy risks, which might cause potential social and economic impacts. The company has to prevent or at least mitigate the data security risk and protect the privacy of personal data.

- When SMEs decide to initiate a digital innovation project, it is recommended to form a project team involving the leaders of different functional departments to work together on the digital transformation project. The company has to avoid letting a certain internal function take the lead of the project and risk the resistance of other parts of the organization. Furthermore, the company has to be aware and address the skills challenges. It should prepare an action plan to enhance the managerial skill, reallocate it to skilled workers, and recruit the necessary skilled workforce to tackle the risk during the development and implementation phase of the digital innovation.

- If the existing processes in an organization are sub-optimal, digitalization of these processes will not result in improved performance. This is aptly captured in the feedback of the Managing Director of an SME, "The key learning is that if the basic process is garbage, then the organization has digitalized the garbage"

- Many SMEs are concerned about business continuity during advanced technology integration and the compatibility of systems. Contingency plans have to be in place during the integration of advanced technologies. Else, it will lead to loss of money, time, and connectedness and result in dissatisfaction with the digital innovation project and process. Digitalization increases the dependency on the technology service providers. During the COVID-19 lockdown, there was concern about getting support and access to maintenance if necessary. The organization's implementation processes will need to be aligned and automated across all initiatives, including product design and development, suppliers, distributors, marketing and sales programs, customer focus, and value delivery through co-creation, human talent and stakeholder management, and business sustainability requirements. Each organization needs to follow a customized implementation of digital innovation based on its shared vision and core competencies.

The interaction with local SMEs showed that currently, most of the digital innovation is focused on improving efficiency of the processes. Digital innovation for new products, or new business models is not yet on the radar of many established SMEs. Furthermore, the analytical ability among SMEs is very low at approximately 80% of the cases. Due to this, SMEs are not able to make the best use of huge amounts of data for digital innovation yet.

6.2. Key Benefits as Experienced by SMEs

Various key benefits were reported by the national experts from India, Singapore, the ROC, and Vietnam, based on their experiences while introducing the DIPG, including the *Digital Innovation Canvas*. These are:

- increased agility and flexibility in responding to customer demands and market opportunities;

- faster design and development reduce the time to market;

- better communication across the organization;
- data-based decision-making;
- easier documentation and retrieval of up-to-date documents;
- proactive prediction and mitigation of the disruptions and reduced time to resolution;
- traceability of goods, documents, work in progress, etc.;
- real-time monitoring and control for greater visibility into orders and inventory to deliver on customer promises;
- 100% adherence to the delivery schedules;
- reduced labor cost due to automating manual processes;
- real-time monitoring of supplier performance at tier 2 and tier 3 levels;
- enhanced process capability (CP/CPK) on parameters critical to quality and safety (>1.33);
- digitalization of quality planning documents (FMEA, control plan, work standards, pre-delivery inspection reports, etc.) for better accessibility throughout the organization;
- shared supplier portal for better integration into the supply chain/supply network;
- paperless compliance management in an audit cloud to enhance consistency and accessibility;
- real-time statistical process control;
- getting a realistic view of what can be achieved in digital innovation in a given timeframe;
- the digital learnings helped to improve the efficiency of the manual processes, reduce the losses, and improve transparency;
- improvement in collaboration across the value chain (reported by most of the SMEs); and
- increase in standardization of the documents, formats, and processes.

6.3. Key Arguments for Convincing SMEs to Implement a Digital Innovation Process

The following selection of arguments is not at all comprehensive and is highly dependent on the SME's current situation, ambition, industry, competitive pressure, and global trends, among other factors. However, business advisors have applied them successfully in their support of manufacturing SMEs. The sequence of the arguments does not indicate any level of importance.

- "Digital innovation means remaining relevant."
- "In many of the challenges you are currently facing, digital technologies can help you."
- "Making your products "smart(er)" will add value to your customers."
- "Digital innovation will help you to better achieve among others your lean manufacturing/ quality/…. objectives."
- "This is an invitation to learn about digitalization by taking a step-wise and manageable approach."
- "With the steps we will take during this project, you will become more digital technology savvy."
- "Digital innovation will help you to become more independent from human resources."
- "Digital innovation will increase your organization's agility to respond to changes in your value chain or value network."
- "As manager of your organization, you have an interest in securing your company's future. You already know that digitalization is a must, even for small companies. However, the challenge is to start at the 'right' end, without jeopardizing your business. With the step-wise approach you will see the benefits and how to realize them in a 'digestible' way."
- "Companies that have embraced digital innovation have experienced measurable
    - productivity gains;
    - reduction in manufacturing cost;
    - reduction in production downtime;
    - reduction in quality cost;
    - reduction in cost of indirect labor;
    - reduction in ramp-up, IT, logistics, warehouse, and energy costs;
    - reduction in time to market, and cycle times; and
    - increase in customer loyalty, based on higher integration with their (IT) systems and/ or based on co-development of digital innovations."
- "Cyber–physical systems expedite traditionally human performed processes."
- "Using digital technologies results in shift to technical skills and productivity gains."

- "Measures can be taken to decrease fears of cyber attacks from digitization."
- "Companies that have explored robotics have seen advantages in
    - improvement of operators' work conditions;
    - better use of production areas (no physical barriers are required);
    - improvement in workspace accessibility;
    - enlargement of production capacity; and
    - improvement in products and process quality" [6].
- "A smart factory concept in SMEs could allow for manufacturing several different products and at the same time, increase the degree of machine utilization, reduce in-process inventory as well as decrease response time in order to meet customer preferences" [7].
- "Digital technologies contribute to the three dimensions of sustainability:
    - economic sustainability: increase in productivity, e.g., by warehouse management systems, data mining to improve the product manufacturing life cycles, and reduction of defect rates;
    - environmental sustainability: analytics model to predict energy consumption, and realize energy savings due to increased productivity; and
    - social sustainability: increased morale among workers due to robots taking over stressful activities (increased automation) and thus increasing safety at workplaces" [7].

6.4. Quote from a Manufacturing Company

"Just a few years ago, we were enjoying success as a classical mechanical-engineering company. Now, we are a solution supplier employing a holistic approach: the machine is no longer the central focus of attention; instead, it is viewed to compete with its peripherals and in the context of integration into our customers' processes.

This, for example, is why we are working intensively on 'digital' topics, such as the acquisition and evaluation of process data for optimization of operation and maintenance. Initial experience gained from pilot projects demonstrates that this puts us on exactly the right road.

Another important subject is the conservation of resources via systems for the minimization of energy consumption, by means of alternative drive arrangements and energy recovery. Here, too, new machines have already proven their worth in practice.

For our customers, all this means: 'better values.' They receive accurately measured data from their processes, are better able to meet their customers' specifications, and make higher profits."

7. KEY LEARNINGS FOR BUSINESS ADVISORS

Based on the support of around 100 SMEs from India, Singapore, the ROC, and Vietnam in developing a digital innovation process, some key learnings for business advisors and consultants have emerged. Providing most valuable support to SMEs in digital innovation requires a comprehensive set of skills including deep knowledge in digital technologies, in managing innovation and digitalization projects, in the SME's industry sector, as well as excellent analytical, project management, and communication skills. During the test of the *Digital Innovation Canvas*, the following key learnings for business advisors emerged:

7.1. Developing Your Own Expertise

A business advisor/consultant will not have the required deep knowledge in all areas of digital innovation that will need to be addressed or will emerge during the discussion on the *Digital Innovation Canvas*. Training in innovation management, digital technologies, and their integration in an SME environment are prerequisites for successful use of the DIPG. Furthermore, as required during the discussion with the SME management, specific technical expertise should be brought in by external subject matter experts to explain the impact, pros, and cons of specific technical solutions in the context of the SME's situation and operations.

With each DIPG assignment, the business advisors will broaden their knowledge in digital innovation at SMEs. In several cases, e.g., during the test of the DIPG in Singapore, it was experienced, "Business advisors, including Singapore Manufacturing Federation (SMF) leadership, had a pleasant engagement process, whereby both parties learned from each other. Business advisors should also seek to engage with larger and more established SMEs so that the learning is a two-way affair."

7.2. Managing Timing and Time

SMEs' willingness to engage in developing their digital innovation process increases with the urgency and the benefits that they can see. The COVID-19 pandemic has put extreme pressure on SMEs. Their supply base was disrupted, and companies had to find new suppliers within a short span of time. Many employees were confined to their homes during lockdowns. SMEs learned about the benefit of more automated or fully digitalized manufacturing processes that could be controlled remotely. During these restrictions, forward-looking SME managers become more interested in finding quick fixes combined with longer-term solutions that would make their companies more resilient even during periods of crisis. The importance of digital innovation is being seen by more and more SME managers. This offers a window of opportunity for business advisors and consultants to support these companies during the digital innovation process using the *Digital Innovation Canvas* along with the related tools and templates.

Adopting digital technologies takes time. Business advisors and consultants need to allocate sufficient time for the development of a digital innovation plan, especially when conducting cost–benefit analysis and risk analysis of what they are recommending, as recorded in a Singapore experience.

7.3. Focusing on Impact and Value

SME management will perceive business advisors' or consultants' support as valuable only if they meet them with a clear agenda and clear objectives. As gleaned from a Singapore experience, even when discussing issues and problems, there should be a structured approach with proper solution options for discussion. This includes support of the SME's management in developing solutions during the development of the Digital Business Canvas as well as during the implementation of the roadmap resulting from the discussion on the canvas. For example, to find the right people to work with data and make good sense of data might be a task for the business advisor. Cooperating with specialists who have experience and knowledge of integration, e.g., those who have AI and machine-learning capabilities, is key to success during the digital transformation.

Good and clear awareness creation, and regular communication is of essence to ensure successful implementation of the proposed plan. Business advisors/consultants can secure the success of the project on digital innovation process if they highlight the importance not only of an experienced project manager, but also of having subject matter experts assigned to the digital innovation project. Furthermore, experience from the ROC shows that the business advisor/consultant should emphasize the importance to communicate the project, its objectives, milestones, successes, and failures in an adequate manner to various stakeholders.

7.4. Broadening the SME Management's Network

Especially in more traditional family-owned businesses, inviting experienced specialists from outside and initiating collaboration with academia/research institutes will bring in complementary expertise and facilitate the change in corporate culture.

When involving other stakeholders, such as external experts during a digital innovation project, the business advisor/consultant should brief them on what to expect and how to participate in the process when interfacing with the SME participants. Experience from Singapore shows that the external experts should have, and exhibit, high interest in understanding the challenges faced by the SMEs and make them understand the benefits of, e.g., the DIPG proposal or solutions being proposed.

7.5. Developing Business Advisors' Proficiency in Digital Innovation Processes

Business advisors need to develop their skills in business administration, innovation management, and digital technologies; and gain practical experience in driving digital innovation projects and transforming SMEs into digital innovation 'champions.' The national experts therefore suggested

- training of business advisors and consultants in innovation management and digital technologies and their impact at manufacturing companies;
- a national platform and mechanisms to coordinate programs and to structure collaborative aligned approaches to achieving the Industry 4.0 vision;
- an online database of successful case studies in local languages;
- a blueprint for transition to Industry 4.0; and
- a policy management approach for deployment of Industry 4.0.

In the longer term, business advisors/consultants engaged in supporting SMEs in their journey to a digital innovation company might consider the documentation and sharing of their learnings with the support of other stakeholders in the digital innovation ecosystem. This will also address the demand for digital innovation and management skill development across all stakeholder groups in the digital innovation ecosystem.

7.6. Developing Consulting Skills to Add Value to the SMEs

During the test of the tools developed for the DIPG with around 100 manufacturing SMEs, the need for systematic digital innovation skill development of business advisors and consultants has been identified. Developing assessor skills in assessing SMEs' digital innovation capabilities, e.g., in Singapore, is just one example of developing the technical skills of business advisors and consultants. However, initiating SMEs' transformation into a digital innovation champion requires more than just an assessment. A strategic view of the SME's future goals and possibilities is as essential as being experienced in the development of digital innovation projects and their successful implementation. Here, the business advisors and consultants need to possess a wide variety of consulting skills and practical experience in rendering digital innovation management support. Apart from the technical skills related to digital technologies, skills in innovation as well as in managing innovation for continued success are needed in combination with comprehensive consulting skills such as

- interpersonal skills;
- analytical skills;
- problem-solving skills;
- transformation/change management skills;
- monitoring/controlling; and
- relationship-building skills.

Looking at the key steps in a typical consulting process, the above-mentioned skills are required by different degrees in specific SME support projects.

Interpersonal and relationship-building skills will be essential during the client relationship-building process, when implementing the identified solution within the SME organization, and when maintaining the client relationship with the SME. Analytical and problem-solving skills will be key to success when identifying the SME's improvement potential, developing the solution to leverage the improvement potential, and monitoring and tracking the performance improvement. Strong problem-solving skills will also be key to success when developing and implementing the solution. During this phase, addressing the underlying reasons for resistance from the client's workforce might also require strong interpersonal skills combined with transformation and change-management skills. Strong monitoring and controlling skills will need to be demonstrated when during the development of the solution, the baseline and the key performance indicators (KPIs) are defined. They help to track the implementation progress and reveal areas where the implementation is not yet on track.

FIGURE 19

BUSINESS ADVISORY SKILLS RELEVANT IN THE VARIOUS STEPS OF THE CONSULTING PROCESS.

	Business advisory skills					
Steps in the consulting process	Interpersonal skills	Analytical skills	Problem-solving skills	Transformation/ change management skills	Monitoring/ controlling skills	Relationship-building skills
Developing client relationships						
Identifying client's improvement potential						
Developing solutions to leverage the improvement potential						
Implementing solutions						
Monitoring/tracking performance improvement						
Maintaining client relationship						

Source: Eva Diedrichs, Chief Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Business advisors and consultants may have already developed some of the necessary skills during their education, and from practical experience. However, systematic development of these skills in many countries is performed within the large international consulting companies based on their tools and approaches. Yet, these consulting firms do not focus on SMEs. This 'market failure' has been addressed by the APO with the development and launch of the DIPG. Special skill-development programs have been launched for business advisors in other countries as well. For example, in 2006, the European Commission launched a program developing "better innovation management support services for SMEs" across the European Union. (It started in 2006 with the European Commission's innovation policy on "developing and testing of better services in support of innovation management." This included the development and implementation of benchmarking tools, training of business advisors in various areas of innovation management, and assessing SMEs' innovation management capabilities.) One of the key objectives was the development of innovation management support tools and training of business advisors and consultants delivering services in innovation management to SMEs.

8. DIGITAL INNOVATION MANAGEMENT SKILL DEVELOPMENT FOR ALL ACTORS IN THE DIGITAL INNOVATION ECOSYSTEM

Successful digital transformation of industries, economies, and regions depends on increasing the skills of all actors in the digital innovation ecosystem. The required skillset includes

- innovation management;
- mastering digital technologies;
- developing effective digital innovation ecosystems; and
- developing digital talents for the various (manufacturing) industries.

However, in practice, the main questions are: who drives the skill development within the digital innovation ecosystem; and how can this effort be orchestrated most effectively?

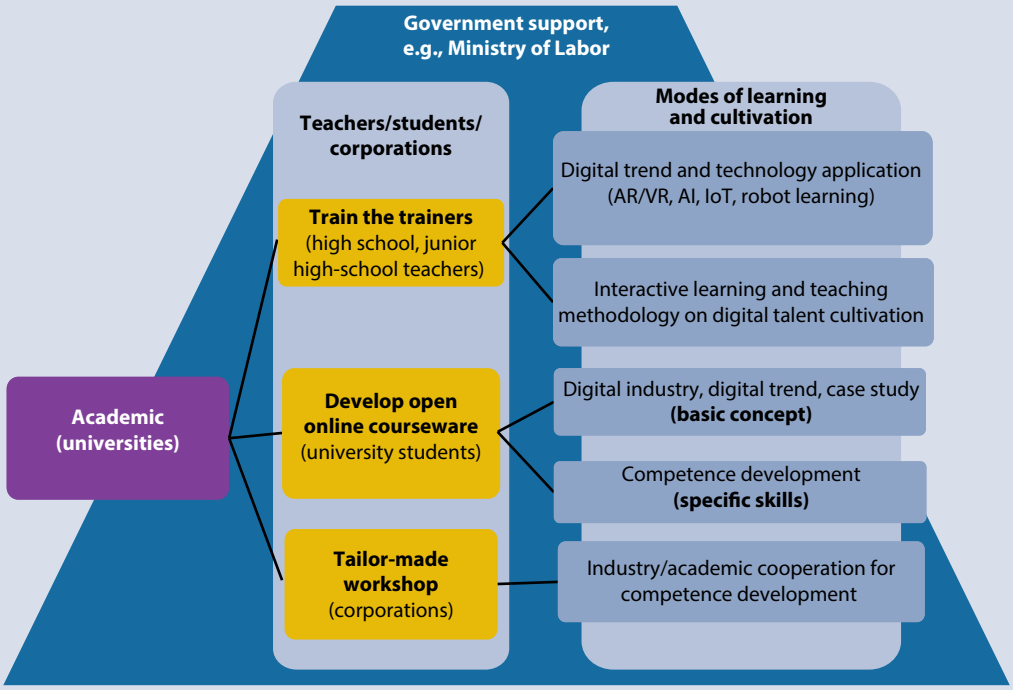
8.1. Driving Skills Development within the Digital Innovation Ecosystem

Skills development within the digital innovation ecosystem is driven by the perceived need, demand for, and supply of the learning and training experience. During the test of the DIPG with around 100 manufacturing SMEs, the SMEs' need for skills development in digital innovation became obvious. However, SMEs' demand for developing these skills was limited. Lack of financial resources, lack of time, and lack of training and education programs were often mentioned as constraints.

Digital innovation skills training is provided in many countries by various organizations. Courses on innovation management are offered, among others, by regular universities, universities of applied sciences, private institutions, and vocational training organizations. Education in digital technologies and how to apply them in an industrial context are offered by centers of productivity, digital innovation hubs, technology centers, chambers of commerce, and trade associations, among others. In some cases, larger companies train staff of their SME suppliers in this area. Software providers and software integrators also offer training to ensure effective use of new software. The focus of skills development at academic institutions differs from that at the other training providers. In academic institutions, the focus is more based on research and on developing analytical skills rather than on the practical application of digital innovation, transformation, and related advanced technologies. To meet immediate demand of manufacturing SMEs, training providers should have a strong focus on the relevance of the training content in practice.

FIGURE 20

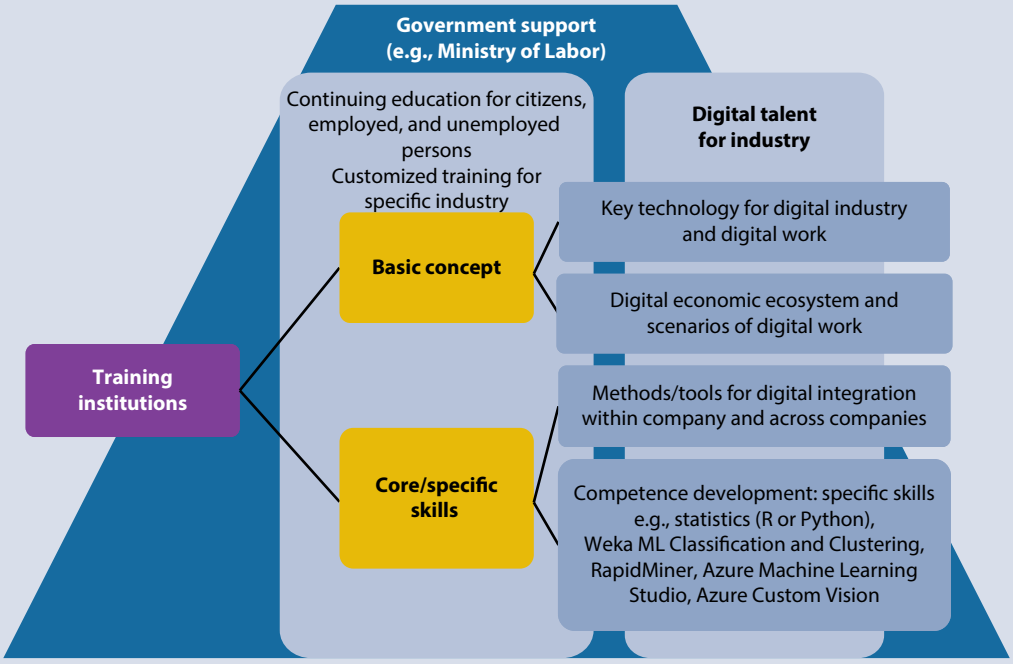
ACADEMIC INSTITUTIONS' FOCUS ON DIGITAL INNOVATION SKILLS DEVELOPMENT.



Source: Lin-Ya Hong, National Expert, ROC, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 21

TRAINING INSTITUTIONS' FOCUS ON DIGITAL INNOVATION SKILL DEVELOPMENT.



Source: Lin-Ya Hong, National Expert, ROC, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Learning factories [9] are promoted that offer a factory-like environment with close to real processes representing steps in a factory's value chain that are required for manufacturing a product. In the ROC's China Productivity Center (CPC), training centers offer this learning environment to develop and apply knowledge relevant for the trainees' day-to-day jobs. Learning factories also offer web-based training or a combination of virtual and on-site training.

Both academic and practical approaches to digital innovation skills development are supported in many countries by national and/or regional governments. The better the public authorities are educated in digital innovation and the challenges SMEs face in this area, the more effective the public support programs can be. Vietnam has defined 'Cohesive and Responsive' as the key theme for their ASEAN chairmanship 2020. Digitalization is key to succeed here. In the UK, the government has developed "the government technology innovation strategy" [10]. Parts of this strategy include

- the recruitment and development of civil servants who are data-literate;
- the development of digital career paths within the civil service;
- the offering of digital, data, and technology apprenticeships for civil servants, and empowerment of leaders to understand and exploit technology innovation through training provided by The National Leadership Centre; and
- exploring seconding senior Civil Service leaders in the industry to allow them to witness the benefits of a culture of experimentation and empowering them to adopt these practices when they return to the government [10].

This example illustrates the permeability within the digital innovation ecosystem, and the interaction among the key players in the digital innovation ecosystem.

8.2. Orchestrating Digital Innovation Skills Development in the Digital Innovation Ecosystem

As digital innovation skills are a rather new requirement, there are not many national or industry-related standards of what are basic, intermediate, and high skill levels. Yet, there is common understanding that these skills need to be further developed to remain competitive and succeed in future. In practice, the digital innovation skills development in SMEs follows mainly a push approach. Only a few SMEs take a pull approach and proactively seek systematic development of digital innovation skills within their labor force. The push approach is driven by many of the other actors in the digital innovation ecosystem.

Based on the experiences during the test of the DIPG, governmental parties should employ every channel available to highlight the importance of digitalization to individuals and business alike. Ministries of education should take the role of defining the criteria that curricula in academic and non-academic institutions have to fulfill. Public education in digital innovation and digital technologies provided by academic institutions, vocational training organizations as well as corporate training centers can secure a pipeline of qualified labor force. The challenge for manufacturing SMEs is to attract these candidates in competition with larger organizations, the public sector, and the startups. Promoting education in innovation management and digital technologies might also reduce unemployment in other areas of the labor force.

Ministries of industries or economics provide funding for SMEs to develop their staff's digital innovation skills. This funding will directly support the skills development within the SME workforce. Effective policies will require the proof of quality of the training providers. Minimum standards for the training content, its delivery, and the qualification of trainers will help SMEs to select the most suitable trainers. Engaging academic institutions and institutions of higher learning to implement the digital innovation policies will enhance the policies' impact. Dedicating resources for communication of digital innovation case examples will further develop the public awareness for digital innovation as a key success factor today and in future.

Trade associations' role is to highlight the importance of digital innovation, share best practices, and offer platforms for experience-sharing and proven approaches suitable for the different types of organizations and different levels of proficiency in digital innovation. They can host (virtual) workshops, seminars, and conferences related to digital innovation. Chambers of Commerce and other intermediaries will also have to think about what support services in digital innovation they can offer to their SME clientele such that it is complementary to the already existing programs and in line with the industries' requirements. It might be necessary to invest in training of business advisors so that they will be sufficiently knowledgeable in digitalization and in managing innovation. This is the prerequisite to properly advise SME clients. Trade associations should develop general training capabilities to be able to train the business advisors and SME clients. They should also have or develop good connections with specialist consultants to help implement more complex digitalization requirements, and where required help address the complex digitalization challenges. International cooperation with intermediaries in developed countries will foster the awareness of and practical knowledge in digital innovation. With the DIPG, intermediaries have a systematic approach with tools and templates available to assist manufacturing SMEs in successfully implementing a digital innovation process.

From the test of the DIPG, a key learning is that consultants and technology providers must have profound tacit knowledge in their specific areas of competence to be able to effectively assist SMEs. Up-to-date knowledge of digitalization trends and technologies is as important as understanding the specific and different needs of manufacturing SMEs. Establishing partnerships with academic and higher learning organizations, as well as with IT- and technology providers will give consultants access to specific areas of knowledge required in a digital innovation project at an SME. Furthermore, academia and institutions of higher learning should engage and work with trade associations to enhance the learning and training process so as to increase the competence of business advisors and consultants.

Public and private investors will assess the manufacturing SMEs' competitiveness and capabilities in digital innovation before investing in them. Therefore, SMEs should have a clear vision and digital innovation strategy/roadmap to convince the investor. Their expectation is that digital innovation will soon be more than just the digitization of data. Digitalization of processes, systems, products, services, and business models will be put on the agenda of the SME's management. This stimulates demand for better skilled labor and for effective training in digital innovation in an SME's context.

To create a pull effect and stimulate the SMEs' demand for digital innovation skills development as well as for trained staff, their customers play a key role. In a B2B sector, larger corporations expect and require more and more integration into their digital systems. They can collaborate with intermediaries and trade associations to communicate their expectations regarding digital integration into their systems and digital innovation.

Consumers will switch to competitors if they offer convenience during the purchasing process, and/or online support for their products. Governments can foster and force digitalization by accepting tax statements and other documents that are no longer paper-based but digital.

Complementary to the key stakeholders in the digital innovation ecosystem, media plays a key role in awareness creation and dissemination of successful approaches to digital innovation in manufacturing SMEs.

9. SELECTED CASE EXAMPLES

During the test of the approach developed for the Digital Innovation Process Guide in India, the ROC, Singapore, and Vietnam, valuable practical experience has been developed. The national experts approached and tested the processes, tools, and templates developed for the DIPG in around 100 local companies, including 30+ in India; 15+ in the ROC; 15+ in Singapore, and 30 in Vietnam. Overall, almost 80 companies completed the process. From each country, five representative cases are presented in this chapter.

The insights and case examples presented in this chapter have been selected to highlight the wide variety of approaches to digital innovation in manufacturing SMEs. The trigger for digital innovation can be very different. In many cases it might be a specific customer demand, or the need to reduce cost in the longer term, while increasing the quality of the product and supporting services.

In each of the cases, the Digital Innovation Canvas has helped the companies' management to identify further opportunities for digital innovation. It has established the basis for a digital innovation process with the aim of transforming the company into a high-performing organization benefiting from digital innovation on a sustainable basis.

The case examples have been provided by national experts from India, the ROC, Singapore, and Vietnam. They are complemented by examples from manufacturing SMEs from Europe.

9.1. Case Examples from India

More than 30 Indian companies have been part of the test. They are presented in Table 17. Of these, the digital innovation journeys of the first five cases are discussed below in more detail. These have been provided by Sanjiv Narula, National Expert from India.

TABLE 17

LIST OF SMEs FROM INDIA THAT PARTICIPATED IN THE TEST.

Case no.	Industry	Year of establishment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
1	Electronics and medical device	2008	12	104	IIoT, cloud computing, big data analytics, fully automated process, traceability, digital product and process as twin, data-based decision making, SAP, ERP integration with customized software	325,000	B2B and B2C

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Case no.	Industry	Year of establishment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
2	Sheet metal, press and blanking parts	1992	28	53	IIoT, cloud computing, localized software, digitalization of quality management, automated process, traceability, real-time monitoring and control	125,000	B2B
3	Sheet metal	2001	19	175	Robotics, cloud computing, localized software, IoT, sensors, analytics, automated process, low-cost automation	125,000	B2B
4	Electronics	2008	12	155	IIoT, robotics, big data analytics, 3D printing, MES, PLM, computer-aided design, low-cost automation	150,000	B2B
5	Medical device manufac-turer	2008	12	150	IIoT, cloud big data analytics, robotics, 3D printing, virtual testing and simulations, flexible manufacturing systems	225,000	B2B and B2C
6	Electrical and electronics sector	2004	16	78	IIoT, cloud computing, big data analytics, robotics, 3D printing, automated operations, fully automated process	225,000	B2B
7	Electrical and electronics sector	2009	11	112	IIoT, robotics, big data analytics, robotics, traceability	125,000	B2B
8	Forging and machining	2003	17	146	IIoT, Cloud, big data analytics, robotics, sensors, customized software's, digital KANBAN, digital work standards, digitally connected processes	325,000	B2B
9	Casting	2005	15	163	IIoT, cloud, SAP, ERP, big data analytics, robotics, 3D printing, digital KANBAN, digital preventive maintenance, visual factory, digital one-point lesson	325,000	B2B
10	Sheet metal parts manufac-turer	2009	17	123	Robotics, SAP, ERP, IoT, 3D printing, predictive maintenance and dedicated software quality control	225,000	B2B

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Case no.	Industry	Year of establishment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
11	Molding	2007	13	132	IIoT, cloud, SAP, ERP, big data analytics, robotics, digital preventive maintenance, and digitally connected processes	300,000	B2B
12	Electrical and electronics sector	2009	11	125	IIoT, cloud computing, big data analytics, and fully automated process	225,000	B2B
13	Forging and machining	2012	12	135	Localized software, IIoT, cloud computing, big data analytics, digital simulations, traceability, fully automated process, forecasting, digital KANBAN and digital preventive maintenance	350,000	B2B
14	Medical equipment manufac-turer	2013	7	85	IIoT, MES, simulations, cloud computing, PLM, CAD-CAM, paperless compliance, and traceability	125,000	B2B
15	Sheet metal	2007	13	75	Robotics localized software, digital simulations, traceability	150,000	B2B
16	Sheet metal	2011	9	115	Robotics localized software	125,000	B2B
17	Electrical parts	2003	17	125	IIoT, Big data analytics, localized software, digital simulations, traceability, CAD, CAM, demand forecasting and digital KANBAN	50,000	B2B
18	Electrical parts	2004	16	135	IIoT, robotics, big data analytics, localized software	150,000	B2B
19	Medical equipment manufac-turer	2008	12	155	IIoT, cloud computing, big data analytics, robotics, 3D printing, MES, PLM, CAD CAM, simulations	125,000	B2B
20	Medical equipment manufac-turer	2012	8	134	IIoT, cloud computing, big data analytics, robotics, 3D printing, MES, PLM and CAD-CAM, traceability	150,000	B2B
21	Sheet metal	2014	6	167	Robotics, localized software, fully automated process, demand forecasting and digital KANBAN	125,000	B2B

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Case no.	Industry	Year of establishment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
22	Electrical sector	2015	5	120	IIoT, robotics, big data analytics, robotics, smart energy systems, digital KANBAN, digital preventive maintenance and traceability	125,000	B2B
23	Electrical sector	2013	7	115	3D printing, MES, PLM, IIoT, digital simulations, traceability	225,000	B2B
24	Electronics sector	2014	6	135	Big data analytics, robotics, sensors, customized software, low-cost automation, demand forecasting, digital KANBAN, digital one-point lesson and digital work standards	325,000	B2B
25	Electronics and medical equipment	2005	15	125	IIoT, cloud computing, SAP, ERP, big data analytics, robotics, 3D printing, PLM, CAD-CAM	350,000	B2B and B2C
26	Molding	2004	16	135	IIoT, cloud computing, SAP, ERP, big data analytics, robotics, CAD-CAM, digital Poka-Yoke	325,000	B2B and B2C
27	Molding and surface treatment	2009	11	175	Digital simulations, traceability, IIoT, cloud, SAP, ERP, big data analytics, automated product inspection and testing and digital preventive maintenance	350,000	B2B
28	Forging and machining	2004	16	125	IIoT, Cloud computing, big data analytics, robotics, localized software, sensors, digital error-proofing systems, real-time tracking of the inventories, online statistical process control and traceability	Confi-dential	B2B
29	Medical equipment manufac-turing	2005	15	135	Cloud computing, big data analytics, robotics, 3D printing, PLM, horizontal and vertical integration, online statistical process control, virtual testing and simulations, digital job instructions, digital document and record control	125,000	B2B

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Case no.	Industry	Year of establishment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
30	Sheet metal	2004	16	113	Robotics, localized software, digital error proofing systems	50,000	B2B
31	Sheet metal	2007	13	165	Robotics, localized software, cloud computing, IIoT, big data analytics and cyber-security, digital Poka-Yoke, software-based gauge calibration and measurement system analysis	325,000	B2B
...							

9.1.1. Electronics and Medical Device Manufacturer Striving for Smart Industrial Production

Background of the SME: The company was established in 2008 as a joint venture between an Indian and an ROC-based organization. It started operations in India for providing electronics and medical devices. Today, the company has about 100 employees. Its evolution has been catalyzed by more than a decade-old partnership with technical and economic collaboration with a Taiwanese partner. Its businesses primarily consist of smart electronic devices, semiconductor devices, smart home gadgets, wearables, smart appliances, and other information and communications services chargers.

Reaction to the digital innovation process: Digital innovation started with the aim to take manufacturing to a firsthand level by introducing the concept of smart factories, by creating smart products using digital technologies. Digital innovation is perceived as a paradigm transferal from centralized to decentralized smart industrial production wherein the operations and manufacturing technology systems are integrated from end to end, with procedures being enhanced through deep insights spawned from real-time analysis of data.

Key actions defined and planned for implementation of digital innovation: The focus was to change from mass production to mass customization with less processing steps; shorter lead time; limited tooling requirement; improvement in productivity, quality, delivery, and safety levels; reduced cost and increased agility; response to customer demands; and faster design and development time. A further focus was to change from global supply chains to distributed production and re-shoring with multi-component consolidation with on-location production. The management also noticed that with the rise of Industry 4.0 technologies, applying digital innovation in their processes not only advances output and quality but also helps in managing the issues in business continuity. The implementation of the digital technologies in the processes of the organization and its key benefits are given in Table 18.

Lessons learned and achievement: The real-time monitoring of supplier performance enabled greater visibility in the value chain and ensured 100% on-time delivery of orders. The process interlocking with the previous 'ok' process cycle ensured that there was no skipping of the processes. The digital technologies helped reduce the inventory costs by 35%, rejection costs by 50%, quality costs by 45%, maintenance costs by 45%, energy costs by 40%, customer defects by 70%, and logistical costs by 30%. Also, they helped improve productivity by 45% and overall equipment efficiency by 35%. Most importantly, they enhanced the business continuity of the organization.

TABLE 18

OVERVIEW OF IMPLEMENTATION OF DIGITAL TECHNOLOGIES IN THE DIGITAL INNOVATION PROCESS.

Process	Subprocess	Tools applied	Benefits
Design and development	• Product design • Process design • Validation and testing • Development	• Digital product and process twin • Big data analytics • Computer-aided design (CAD) • AutoCAD, Catia. • Product life cycle management (PLM) • Testing and validation infrastructure	• Increased agility and flexibility in responding to customer demands and market opportunities • Faster design and development time • Better communication across the organization • Data-based decision making • Easier documentation and retrieval of up-to-date documents
Incoming Inspection and testing	• Part inspection • Process capability monitoring	• Vision inspection system • Performance test rigs integrated with IoT, i.e., sensor and analytics software • Manufacturing execution systems (MES) • Online software for process performance (Pp) and process performance index • Cloud-based technology • Digital gauge management • Cybersecurity	• Traceability • Real-time monitoring and control, capability studies, control charts • Reduction in the quality defects and cost • Faster corrective action preventive action (CAPA) • Data-based decision making • Easier documentation and retrieval of up-to-date documents
Electronics parts soldering Surface mounting technology (SMT)	• Solder paste softening • Laser marking • Printing circuit board (PCB) printing and cleaning • Solder paste inspection (SPI) • Pick and place • Reflow oven soldering • Automatic optical inspection (AOI)	• Manufacturing execution system • Machine learning • Bar code scanning and QR codes • ISO class 8, cleanroom facility • Automated guided vehicles (AGV) compatible shop floor • Collaborative robotics • SAP and ERP • Auto retrieval of reels • Cloud computing • Data analytics • Cybersecurity	• Traceability • Automatic program changeover and bill of material (BOM) verification • Biometric access control • Real-time monitoring and control, capability studies and control charts • Reduction in quality defects, cost, and machine downtime • Process interlocking with previously 'ok' process cycle • No process skipping and no part processing of not ok parts • Automatic OK decision based on optical inspection data • Predictive maintenance • Improvement in the productivity, quality levels, safety level with reduction of cost. • Faster corrective action preventive action • Data-based decision making • Easier documentation and retrieval of up-to-date documents

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Process	Subprocess	Tools applied	Benefits
Electronic parts assembly	• Laser marking • Assembly of the outer body and miscella-neous electronic child parts	• Manufacturing execution system • Machine learning • Bar code scanning and QR codes • Collaborative robotics • Cloud computing • Data analytics • Cybersecurity	• Traceability • Automatic program changeover and bill of material (BOM) verification • Biometric access control • Real-time monitoring and control • Capability studies and control charts • Reduction in quality defects and cost • Decrease in downtimes • Faster corrective action, preven-tive action • Data-based decision making • Easier documentation and retriev-al of up-to-date documents
Performance testing	• Internal circuit testing • Functional testing	• Automated testing machine • Manufacturing execution system • Machine learning • Bar code scanning and QR codes • Collaborative robotics • Cloud computing • Data analytics • Cybersecurity	• Traceability • Automatic program changeover • Real-time monitoring and control, capability studies and control charts • Automatic "ok" decision based on optical inspection data • Reduction in quality defects and quality cost • Easier documentation and retriev-al of up-to-date documents
Customer support	• Sales and service • Customer relationship manage-ment	• SAP, ERP integration with customized software • Shipping status tools: alerts and updates • Cloud computing • Data analytics • Cybersecurity	• Increased agility and response to customer demands • Increased agility and flexibility to respond to customer demands and market opportunities • Real-time monitoring and control for greater visibility into orders and inventory to deliver on customer promises • End-to-end visibility across the value chain • Faster corrective action preven-tive action • Data-based decision making • Easier documentation and retriev-al of up-to-date documents

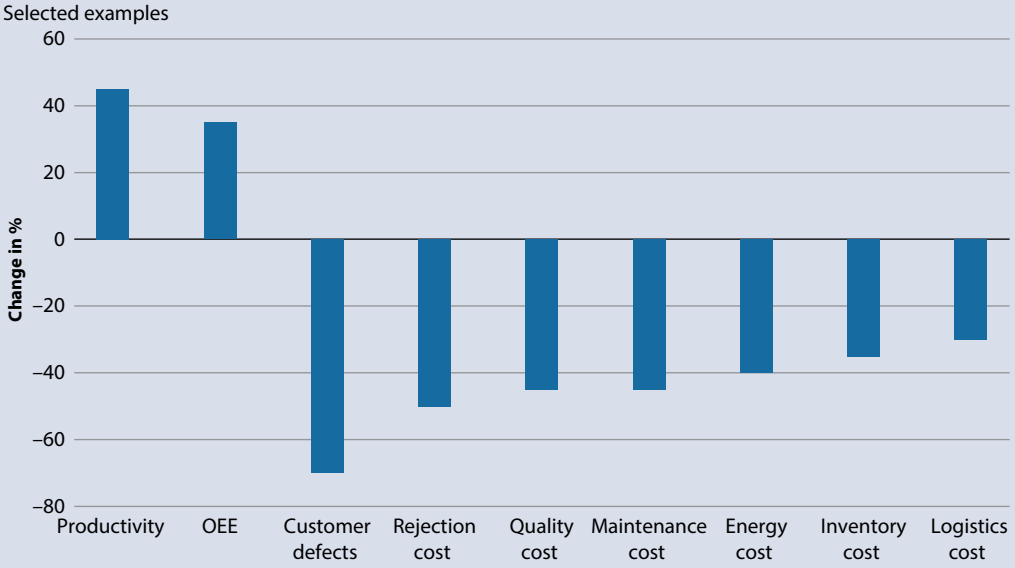
The appropriate prioritization and implementation of I4.0 technologies helped achieve the next level of productivity, though reaching there was not easy. There is no one-size-fits-all answer, given the diversity of the manufacturing industry and divergent ranks of maturity associated with I4.0 technologies. Machinery suppliers emphasized on process control systems, manufacturing scheduling optimization provisions, predictive maintenance, and systems to improve the overall equipment efficiency while confirming that they see software as a separate revenue pool and have

adequate in-house talent. Automation providers focused on hardware-linked technology aspects such as plant-based manufacturing equipment and systems and automatic material management. The top management ensured the partnerships with companies with electronics assemblage familiarity and software service providers, to offer a collective product for carefully chosen hardware and software technology aspects. Most of the experts believed that the future of lean management at the company lay in digitalization.

FIGURE 22

EXAMPLES OF PRODUCTIVITY GAINS.

Productivity gains from I4.0 and digitalization (in %).



Note: OEE = Overall equipment efficiency.
Source: Sanjiv Narula, National Expert, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

The manufacturing execution systems (MES) providers ensured software linked I4.0 technology aspects and integration with the existing manufacturing setups to provide unremitting amalgamation with manufacturing machines and equipment. The MES service providers had partnerships with instrument providers to gain specific acquaintance of hardware for simulation of the machines' behaviors and patterns. The organizations faced barriers related to the challenges of high investments with long and uncertain amortization, coupled with a low degree of maturity of digital technologies and fear of data security, including the theft of industrial trade secrets and intellectual property. The organization also faced a lack of clear standards for I4.0; multiple, but isolated efforts with limited coordination among all stakeholders; lack of deep-level understanding; and issues related to redesign of the facility layout.

9.1.2. Component Manufacturer Adopting Digital Innovation in Journey towards Industry 4.0

Background of the SME: Established in the year 1992 with 53 employees today, the company is manufacturing and supplying a genuine range of industrial products that find broad application. The company is a premium supplier to large manufacturers supplying high-quality products like press parts, washers, brush plates, brush holders, and brackets. Intending to enhance productivity and improve efficiency, the company opted for digitalization of certain business processes.

Reaction to the digital innovation process: The need for digitalization was created by increased product range and high demands and expectations from the customers. The management took a conscious decision to digitalize processes in their selected operational areas including quality management, maintenance management, and productivity management. With the transformation to Industry 4.0, the demands from customers have been increasing. Customers expect digitalization, data availability, data security, data visibility, and analytics.

Key actions taken and planned for implementation of digital innovation: A preliminary initiative for digitalization of all quality-related issues and digitization of documentation was taken. Early gains were observed in terms of the streamlined complaint resolution process and document management. The actions taken in digital transformation are given below:

1. **A digital supplier portal dashboard is created in the digital QMS framework:** This digital dashboard displays the complete status of supplier-wise customer complaints. At a glance, this dashboard provides supplier-wise number of complaints raised versus the number of open complaints, closed complaints, overdue complaints, approved complaints, and completed complaints. Once the complaint is registered, it is automatically transferred to the respective supplier. The supplier is then informed via email. Any action taken by the supplier on the customer complaint is visible to the customer, who then can either approve or disapprove the action taken by the supplier. Furthermore, the digital platforms help track supplier improvements and create a repository of all actions taken by the supplier against the complaints raised by the customer.

   The actions taken by the supplier against a complaint raised are visible in real time to the customer, who then can assess these actions. These actions can be 8D analysis, Kaizen, CAPA, or Poka-Yoke. The customer can either approve or disapprove these actions taken by the supplier. This also helps in the real-time monitoring and control–capability studies, control charts, reduction in the quality defects and costs, faster CAPA, and data-based decision making.

2. **Machine-to-mobile IoT connectivity is implemented within the plant:** This is done on all legacy machines to get productivity data automatically and monitor repetitive losses.

   Machine-to-machine connectivity provides the solution for vertical integration within the plant for data acquisition from machines/devices to do advanced analytics on mobile phones for the plant performance. Supporting the concept of leveled production planning, it facilitates optimum use of plant and machinery, with minimum inventory levels at each stage. This factual data collection in real-time mode is used for OEE calculation and production process losses (PPL) analysis. This way, the senior management always carries plant status on their mobile phones.

3. **Digitized audits and closed-loop compliance management:** The audit cloud helped to keep a proactive check on all process parameters and daily tasks, audits, and compliances. It not only helped them to increase productivity and performance but also made their entire process paperless. Registering all internal and external customer complaint in the cloud, root cause analysis, and planning of improvement action for complaint resolution in real-time, this system allows a customer to raise complaints to suppliers and has a direct interface with suppliers. Herein, a complete digitalized framework of improvement

management is available with suppliers. Any action completed by a supplier is visible to the customer. Most of the actions taken in the digital transformation of the organization are focused on productivity improvements. Going forward, the organization is planning to use the digital innovation process for transformation of the business models and development of new products and offerings. Toward that end, the following activities are planned:

- evaluation of the digital innovation maturity by a service provider;
- identification of pilot projects;
- training of team members on the digital skills with special focus on advanced and predictive analytics; and
- digital twins in new products development and supply chain management.

Lessons learned: The feedback from top management of the organization highlights that the COVID-19 pandemic is accelerating I4.0 implementation and digital workflows across industries. The vital need to plan a smarter, robust, flexible, and agile value chain has been one of the key lessons of the pandemic. Some notable points are:

- defects prevention through proactive daily work management, process monitoring, and compliances;
- enhanced productivity with machine-to-mobile connectivity; and
- process converted to smooth flow.

Achievement: With these digitalization measures undertaken, the company is now an 'Approved Green Vendor' with a large organization. The digital innovation has helped the organization to improve its quality and productivity levels. Going forward, it is planning to implement the DIPG in all areas of the organization, particularly for the automation of the design and development process to reduce the dependence on manpower and ensure business continuity while managing social distancing norms.

9.1.3. AMD Engineering Deploying Excellence Framework in Manufacturing Value Chain to Achieve Excellence in Quality, Cost, and Delivery

Background of the SME: This family-owned company had a humble beginning in 1976 as a light fabrication unit in the state of Maharashtra. Over time, it evolved into a system supplier capable of designing, developing, and manufacturing components, assemblies, and modules for the manufacturing industry. Today, the company is TS 16949 and ISO 14001 certified and has eight independent manufacturing plants across India with 200+ MSMEs in its network as suppliers.

The need for a digital innovation process: With an increasing supplier base and the need for an integrated communication channel between the company and its suppliers in a real-time manner, the company approached a technology service provider. The top management, the service provider, and a large organization (customer) analyzed the need and found out three key areas to be addressed. There was a need for

- a connected and collaborative framework between the company and its suppliers for integrated communication, reduced traveling, and time savings;
- availability of factual and historical data as basis for informed decision-making and management review; and
- traceability of customer complaint raised against the supplier and improvements undertaken to resolve these complaints.

As a pilot module, the company deployed a closed-loop complaint management system for the company and its suppliers to monitor all the complaints raised by the company to its suppliers. With the help of this system, the company was not only able to monitor and track its complaints but also assess the improvements made by its suppliers to resolve those complaints digitally. The company further analyzed trends in the documented complaints for individual suppliers, which helped implement a vendor rationalization program effectively and transparently.

This system allows a customer to raise complaints to suppliers via a direct interface with the suppliers' quality management system. A complete digitalized framework of improvement management is available for suppliers. Any action completed by a supplier is visible to the customer. Customers can assess suppliers' actions in response to the complaint and can either accept or decline. If their action is accepted, then the complaint is closed in the supplier's QMS, and if it is declined then the complaint remains open. In this way, all complaints are managed through a single-window dashboard in real time.

Key actions the company will take after having gone through the *Digital Innovation Canvas*: On successful implementation of the pilot and with encouraging results for both suppliers as well as the company, it further deployed the 'supplier excellence framework' for deeper integration with its suppliers, with the help of service providers.

This framework not only ensured supplier's deliverability as per required quality, cost, and delivery schedules but also created an atmosphere of confidence and transparency between the suppliers and the company. The company also achieved paperless collaboration between the company and its suppliers, indirectly contributing positively to the environment. A digitalized supplier excellence framework is established between the customer and the suppliers, which provides the customer with regular updates on various activities and processes occurring at the suppliers' end related to part-wise inspection compliance, audits, tools-and-dies maintenance, gauges calibration, etc.

Lessons learned: With the help of digital innovation in the excellence framework, the company was able to achieve the following targets:

- real-time integration of supply chain for concern management, audits, and compliances, gauges calibration and maintenance, change management, new product development, etc.;
- lot-level traceability in the supply chain for failures and recalls;
- monitoring of all suppliers' improvement projects and tasks from completion and timeliness perspectives;
- monitoring of part-wise technical compliances by suppliers;

- keeping track of supplier-wise, part-wise, and defect phenomenon-wise parts per million (PPM); and

- creating a proactive approach in new product development with digitalization.

Achievements: The company has achieved a time-bound paperless and real-time communication with suppliers to resolve all complaints effectively. This effective collaboration with suppliers has benefitted the company in many ways, like monitoring supplier performance through the system, reduction in quality defects and losses, reducing unnecessary visits to suppliers during the COVID-19 pandemic, and changing supplier support mechanisms from reactive to proactive mode. This has also helped in ensuring 100% delivery of the parts. Further, the organization plans to implement digital innovation in all aspects of its value chain.

9.1.4. Sheet Metal Manufacturer leveraging Digital Innovation for Redesign and Development of its Supply Chain

Background of the SME: Established in 2001 in the industrial hub of Pune, the sheet metal manufacturer is serving the increasing market demands for high-quality sheet metal components. With 19 years of rich experience in the sheet metal industry, the organization is a world-class manufacturer of sheet metal parts. It was undergoing a level of disruption that has never been seen before due to the COVID-19 outbreak. The restrictions and lockdowns posed by COVID-19 (April–June 2020) consequently interrupted the availability of material and manpower, which lead to the disruption in the global value chain.

The organization had started its digitalization journey in 2018. Before the COVID-19 outbreak, digital innovation was a topic of enormous curiosity in the organization and its supply chain partners. It was a stimulating theme with enormous potential benefits and was generally viewed as a 'positive' and forthcoming topic. I4.0 is not only as significant as it was before the outbreak, it seems to be even more relevant moving forward. I4.0 technologies are also helping the organization to implement the state-of-art technologies and transform it into a more resilient organization in the medium to longer term.

Reaction to the digital innovation process: Years of globalization and lean optimization in engineering have led to multifaceted, multitier, and complex supply chain networks. Due to the outbreak, various forms of restrictions are in place, which have consequently affected the supply chain and operations. With lean and globalized structures, the operations and supply chain of the organization have turned out to be explicitly prone to the outbreak of the coronavirus. The leadership of the organization strongly believes that the digital innovation process has the capability of supporting all the aspects of the supply chain, including design and development, supply chain, manufacturing, and service. This perception has created an instant value as the pandemic is expanding its hold. The idea of a completely functional industrial unit with a minimum workforce may help to continue production without any constraints, especially during the COVID-19 phase.

Key actions taken and planned for the implementation of digital innovation: The administration has already initiated the implementation of digital technologies for minimizing the impact of COVID-19. Cloud technologies have been implemented for real-time tracking of input material, raw materials, child parts, work in progress, and finished goods. Augmented reality built on mobile technologies is being planned to enable the workforces to carry out critical tasks with remote advice of experts working from home. This helps minimize the opportunity loss even during this crisis posed by COVID-19. The organization expects that by integrating digital technologies with

the contemporary systems, the 'Factory of the Future' as well as the 'Supply Chain of the Future' will be networked, harmonized, and made scalable in terms of both organization and processes. They will also be able to anticipate changes and adapt to newfangled requirements with agility. The production processes, machinery, workforces, supply chain, and consumers will be linked, providing real-time data. The organization is planning to implement the following activities to fast-track the digital innovation process:

- measurement and evaluation of the digital innovation quotient level to determine the digital readiness along with a consultant;
- finalization of the digitalization vision and roadmap for digital transformation journey and operationalization of the digital strategy;
- making micro-level plans for the 'smart factory' and 'smart value chain' concepts including the technologies, approaches, structures, and procedures;
- execution of pilot projects;
- implementation of advanced analytics and data science; and
- training of team members in digital skills.

Lessons learned: The smart amalgamation of lean manufacturing with the possibilities of digital technologies makes the organization's processes faster, more flexible, and more adaptable. At the same time, it opens up potential for new revenue, value creation, and business continuity, particularly in times of COVID-19. Apart from the expected benefits, there are certain risks and challenges for professionals who are implementing digital technologies. These include

- lack of digital and non-digital skills;
- technology interface problems due to communication issues between devices, lack of decision logic/standards, etc.;
- high investment in digital technologies with lack of clarity on the returns and no clear measure available to decide the viability of investment in digital technologies; and
- internal resistance and corporate culture.

9.1.5. Developing a Digital Supply Chain System for Scheduling, Delivery, and Advanced Shipment Notification (ASN) Management

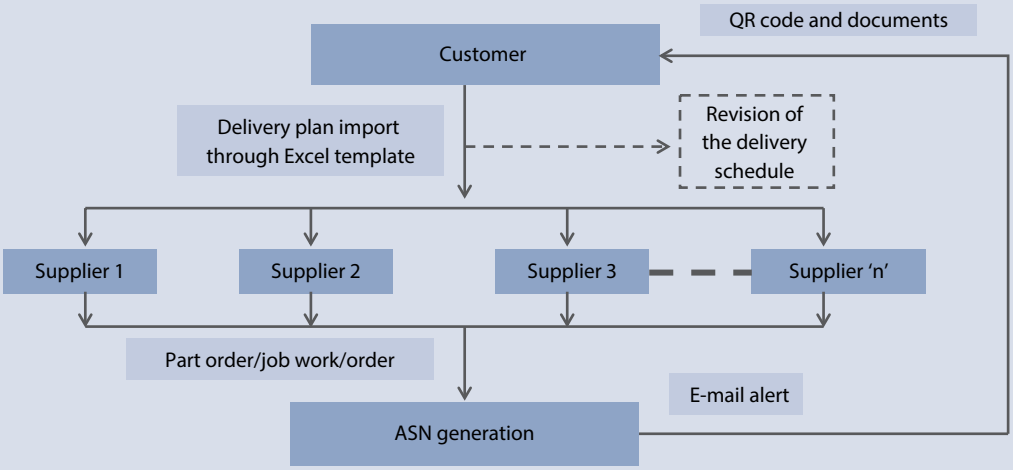
Background of the SME: The company is one of the leading manufacturers of blanking parts. For more than 100 years now the company has pioneered the development, production, marketing, and servicing of state-of-the-art braking systems. In 2017, the company started its India operations and manufacturing plant in the year 2007 in Pune, about 150 km southeast of Mumbai. The company has a supplier base of 30 suppliers providing child part material for blanking parts.

Reaction to digital innovation process: The company provides a monthly schedule to all its suppliers for the child parts requirement. The schedules do get amended in between (during the

month) as per the company's customer demands. To keep track of all these schedules, revisions, and supplier deliveries is a cumbersome task to manage. So, the introduction of digitalization to streamline and efficiently manage all these activities was paramount. The company, with its digitalization partner, deployed a digital supply chain system, which created a smooth flow for the suppliers as well as the company.

FIGURE 23

DIGITAL SUPPLY CHAIN SYSTEM FOR ASN MANAGEMENT.



Key actions the company will take after having gone through the *Digital Innovation Canvas*: The company now submits the part-wise/day-wise monthly schedule for all suppliers via this system. The instances of these systems are deployed at both the company's end and the suppliers' end. Any revision in the schedule is done by the company on the platform itself. This gives real-time notification on the revision in the form of email alerts to the suppliers.

The supplier, on the other side, when dispatching material against the schedule, generates an advance shipment notification (ASN). The ASN alert is sent to the company along with the QR code comprising ASN details and other child-part-related information.

Lessons learned and achievements: With the help of digitalization of the supply chain, the company was able to achieve the following targets:

- ASN from the supplier for the material to be received;
- streamlined process of customer supplier relationship for delivery management;
- 100% on-time delivery;
- increased agility and flexibility to respond to customer demands and market opportunities; and
- real-time monitoring and control for greater visibility into orders and inventory so as to deliver on the promises made to the customer.

9.2. Case Examples from the ROC

The following case examples have been developed by Lin-Ya Hong, National Expert from the ROC.

The DIPG enables SMEs to challenge prior assumptions about their products, service portfolios, and decision-making processes and to transform to a more flexible and agile management based on data analytics. With thoughtful and clear guidance and instruction, the missions and goals of SMEs can be realized using a detailed action plan and various methods adopted to implement the digital innovation process step by step. During the vision workshop in preparation of digital innovation, SMEs became aware of the environmental uncertainty, risks, and the internal and external key drivers and actors that they need to consider in order to develop a more realistic goal during the process. In addition, SMEs can also recognize the implementation of digital innovation process as a systematic approach that has to incorporate various positive and negative feedbacks. They should also find ways to motivate and engage key staff and partners in the digital innovation ecosystem.

The support from government policy and the collaborations with academic sectors are the key driving forces for SMEs to engage in the digital innovation process. A challenge SMEs face is in ensuring data security, given that the internet is a critical factor in smart manufacturing processes. SMEs have highlighted the importance of data security in maintaining smart manufacturing systems as well as in digital processes. The need for cultivating digital talent and right skills is an essential element in the digital innovation process. Companies have to learn to create an open and friendly atmosphere that encourages their employees to engage in the digital innovation process and motivates their staff to learn and apply the digital technologies in an efficient manner.

The following five case examples have been selected from 15 SMEs in the ROC that have developed the *Digital Innovation Canvas* for their organizations and used it to develop their digital innovation processes. The first five cases presented in Table 19 are discussed in more detail below.

TABLE 19

LIST OF SMEs FROM THE ROC.

Case no.	Industry	Year of establish-ment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
1	Metal manufacturing	1965	55	150	Cloud ERP system	350,000	B2B and B2 C
2	Baking equipment industry	1982	38	140	Cloud automation	500,000	B2B and B2C
3	Electric and machinery industry	1988	32	200	Sensors and image recognition technology	400,000	B2B
4	Plastic industry	1979	41	200	SAP cloud platform	350,000	B2B and B2C
5	Automotive part production	1965	55	120	Big data and analytics	3,330,000	B2B and B2C
6	Medical and healthcare industry	1988	32	196	AI and big data	166,000	B2B and B2C

(Continued on next page)

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Case no.	Industry	Year of establish-ment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
7	Plastic industry	1981	39	192	IoT	120,000	B2B and B2C
8	Electrical appliance	1996	24	196	Collaborative robot	170,000	B2B and B2C
9	Cosmetic industry	2002	18	96	Digital marketing	100,000	B2C
10	Electronic industry	1991	29	62	Collaborative robot	350,000	B2B and B2C
11	Chemical industry	1989	31	50	Cloud ERP software	100,000	B2C
12	Beverage industry	2009	11	120	Automated detection, count and analysis system	100,000	B2C
13	Electronic industry	1978	42	200	SAP digital manufacturing cloud	300,000	B2B
14	Machinery industry	1990	30	70	Advanced manufacturing, cloud of things/ AVM	350,000	B2B
15	Textile industry	1988	32	120	Big data analytics	300,000	B2B and B2C
...							

9.2.1. Developing a Niche Market Through Product Innovation

Background of the SME: STE metal manufacturing company was established in 1965, and today it has 150 employees. The company has met ISO standards. Its testing facility laboratory has been certified and authorized by a globally known international organization before it applied digital technology to the existing management and manufacturing processes. Its professional range of products includes lever locks, cylindrical locks, interconnected locks, and mortise locks for commercial, academic, and government buildings as well as for other public accommodations or private entities.

Reaction to the digital innovation process: In the beginning, the company mainly manufactured low-end grade-3 locks, which yield low profit margins at fierce competitive market price. The company would like to increase the sales and customize the products for high-end markets with smaller volumes and better margin. The CEO of the company is fully supporting the application of digital technologies to develop a niche market for continuous growth.

Key actions the SME will take after having gone through the *Digital Innovation Canvas*: Since the company has over 50 years of technical expertise in the field, the applied digital technologies have increased visibility and improved efficiency for suppliers, logistics, and vendors. It has also facilitated the interdisciplinary cooperation with electronics, communications, and biometrics industries to successfully develop smart locks. Now the company is planning to invest resources and funding to integrate and upgrade its products with IoT for smart-home and smart-building applications with the cooperation of relevant research institutions, by developing functions that link facial recognition, wireless communications, and mobile apps.

Lessons learned: In order for a traditional lock manufacturer to transform and upgrade to a technological security system provider in the modern digital era, the company has defined different stages for introducing the digital technology into the organization. A clear vision of 5–10 years and an action plan were developed in discussion with the key leaders of the company. One essential learning during the digital innovation process was to integrate different systems with the latest information and communication technologies and involve key stakeholders across industries and digital innovation ecosystems to achieve the transformation.

9.2.2. Navigating the Success of Second-generation Business through Digital Innovation

Background of the SME: KEM baking equipment company was founded in 1982. Today, it has 140 employees and a wide range of products including baking trays, loaf pans, bakeware series, storefront supplies, trolleys, and measuring and decorating tools. The company faced the issues of wage increase, talent shortage, and supply shortage. The first digital innovation project was kicked off in early 2013, but it failed due to the shortage of digital talent and the lack of prioritizing the vision and action plans.

Reaction to the digital innovation process: KEM is a family-owned business. When the second generation took over the business, it wanted to change the management process through digital technology. Reaching the consensus was tough, and the issue was discussed among all the key family members. Since the company has learnt the lesson from previous experiences, a 5–10 years blueprint was proposed in 2017. It took a series of steps to steadily expand the factory size and successfully adopt the digital innovation technologies for the automatic product line and the automatic welding robot.

Key actions the SME will take after having gone through the *Digital Innovation Canvas*: Nowadays, automated production and robots are extensively used in the manufacturing industry and have become an essential element in the manufacturing processes. The introduction of automation in the manufacturing process has enhanced the quantity of production and also reduced a major part of labor cost to meet the customized market demand. The success of digital innovation has increased sales by 40% and productivity by three times. The company decided to allocate 10% of the profit on continuing research and development. It also established a rewards system to encourage employees to participate in the related digital-knowledge workshops and training sessions organized by the government and research institutions. Now the company is focusing on social media marketing to strengthen its brand image to increase revenues from products and services in the domestic and international markets.

Lessons learned: The family-owned business faced more challenges during the digital transformation process as the business grows or new business model develops, especially when the company has failed in the first digital innovation project. Most of the key family members became more conservative on the digital technology application after the failure. Therefore, the company has slowed down the second digital innovation process and invited more experienced specialists from outside. It also initiated collaboration with the academia and a research institute to facilitate the implementation of the digital innovation project. After the success of the implementation, the CEO of the company has put more emphasis on communication to transform from the significant control by core family members to a more agile management.

9.2.3. Building a Positive Feedback Loop across the Digital Innovation Ecosystem

Background of the SME: AC electric and machinery company was established in 1988 and has 200 employees today. The company has met and implemented international qualification standards

on management and manufacturing process. It is one of the leading companies in providing electric and machinery parts to B2B markets and has generated a stable profit with its existing business model and manufacturing process.

Reaction to the digital innovation process: Since the company has a long history in the industry and enjoys stable growth and revenues, it is hard to convince the stakeholders that the adoption of digital technology will lead the company to a higher level and generate more profits and reputation. Many of the stakeholders are afraid that the digital innovation project will fail, which will lead to the side effect of lower production due to the integration cost and impact on the innovation process, thus resulting in a decline in profits.

Key actions the SME will take after having gone through the *Digital Innovation Canvas*: The company has developed and is applying smart manufacturing technologies to produce high-quality products. After the company successfully launched the sensors and image-recognition technology in the manufacturing process to precisely detect a malfunction and lower the material cost in its ROC factory, the company is planning to apply the technology to its factory abroad to maximize the production volume and reduce the manufacturing and material costs while increasing the revenue. The company is preparing to sell the upgraded sensors and the image-recognition module to other industries for generating a new profit stream.

Lessons learned: Investment in digital technology is a long-term process that requires sufficient working capital. Funding is one of the key challenges that prevent SMEs from investing and adopting the digital technology in the beginning. After the implementation, the company has to always be prepared to invest additional resources in digital skills training and keeping the software and technologies updated. It also has to come up with an added value solution or additional market potential in return for the IT technology it invested in. Collaborations with research institutes and government agencies have lowered the risk of implementing the digital innovation process. The company can consult skilled and experienced experts to acquire more information and related resources during the implementation process.

9.2.4. Developing an Open Culture to Facilitate the Transition Triggered by Digital Innovation

Background of the SME: BM manufacturing company was founded in 1979. Today, it has 200 employees. The company has produced filters for B2B and B2C markets. It applied an ERP system and replaced it with an SAP system. Now it is upgrading its software and hardware by SAP cloud platform modules one by one in order to enhance the capability for product differentiation and achieve enhanced customer satisfaction through higher communication efficiency and productivity.

Reaction to the digital innovation process: Most of the employees are open for digital innovation projects and believe the technology will lead to more efficiency and productivity. However, when implementing a new system to replace the old one, the employees have to deal with the changes and potential risks during the digital innovation process. The company has to organize regular meetings to evaluate the progress and performance and also provision additional training resources to develop the employees' skills in risk-taking during restructuring. The staff needs to be equipped with the necessary skills to respond to uncertain changes and challenges. Furthermore, the company has established a communication-and-reward mechanism to encourage the staff involved in the process.

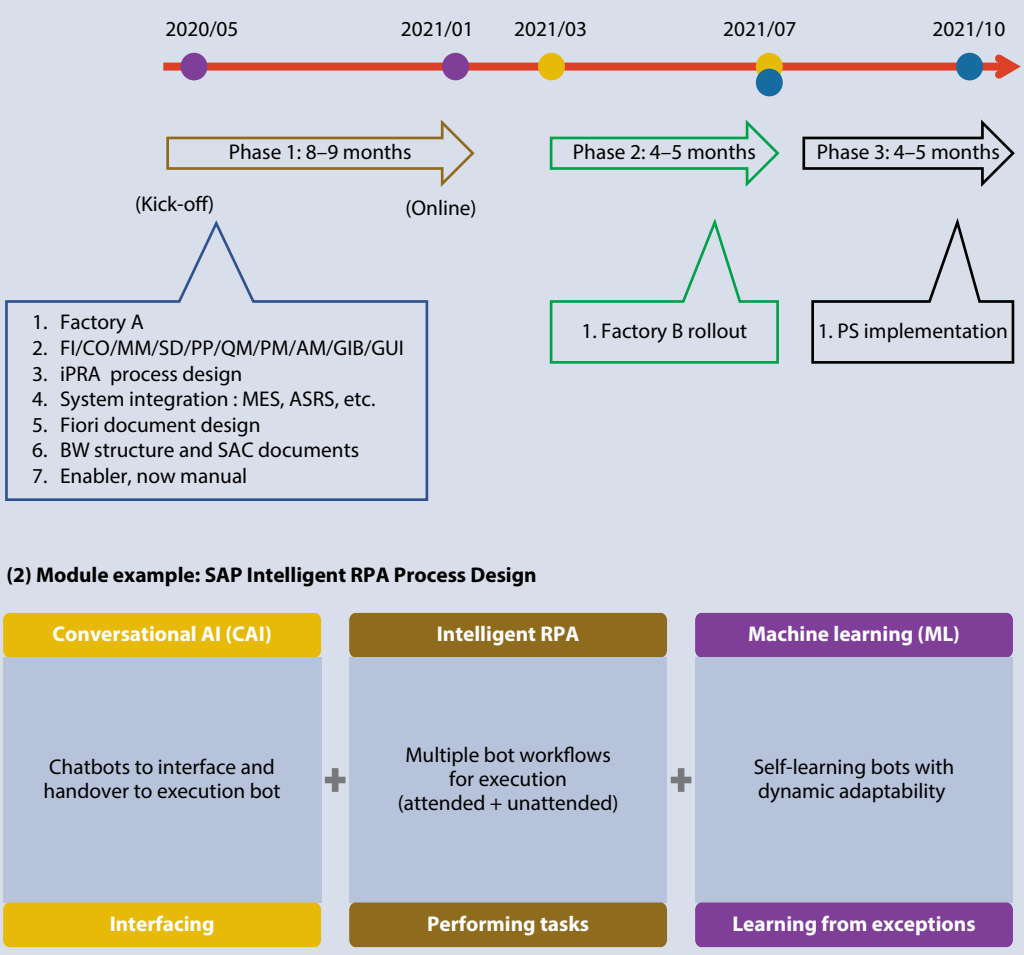
Key actions that the SME will take after having gone through the *Digital Innovation Canvas*: The implementation of the digital innovation project has lowered the material and inventory costs.

The employees can also access the coherent data and collected information instantly. The company has set up regular meetings for evaluation of the project's performance after the implementation. Now the company is planning to invest in long-term digital talent recruitment and development. Since the skills, knowledge, and attitude of a company's employees affect how digital technologies are applied and implemented in the long term, the company is preparing for the future workforce to maintain its competitiveness and make the key staff more motivated and involved.

An example roadmap for implementing the digital innovation process: The roadmap for implementing the digital innovation process of BM manufacturing company began with an assessment of the company's current digital maturity and the definition of a future vision. It then systematically identified the gaps regarding the peoples' skills, processes, technologies, and content. Steps to close these gaps can be built into the roadmap. Since digital transformation takes place over several years, understanding the KPIs and the RoI for each phase helps to keep a multi-year journey on the right track. With a structured approach, all of the moving elements and parts can be managed and progressed.

FIGURE 24

EXAMPLE ROADMAP FOR THE DIGITAL INNOVATION PROCESS.



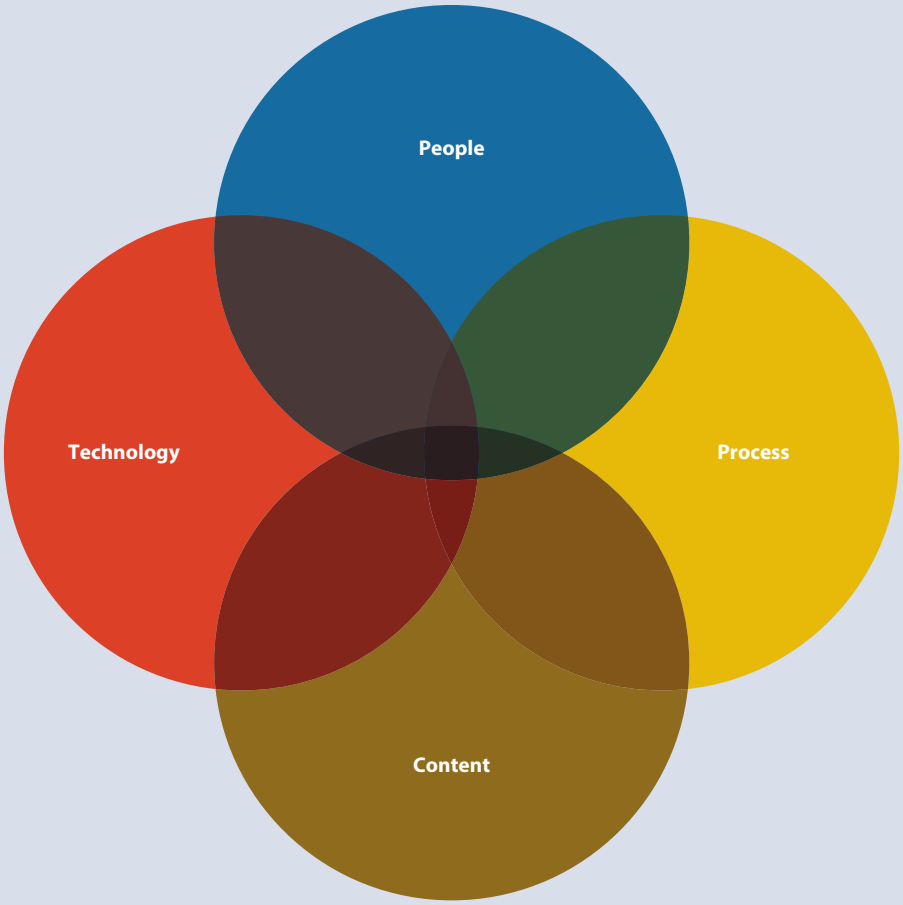
Source: Lin-Ya Hong, National Expert, ROC, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

There are four major success factors of the roadmap for the digital innovation process:

- **People:** They include the customers, suppliers, business partners, company employees, and other key stakeholders involved during the cross-functional collaboration.
- **Processes:** These include customer experiences and digital marketing strategy development, online order management system, order fulfillment and warehousing automation, products, and automation to maximize organizational efficiency and achieve the scalability for the digital business model.
- **Technology:** It builds on an integrated information infrastructure, including data analytics and data management, as well as cloud services to serve as a foundation for integrating data and predictive data analytics that drives growth.
- **Content:** It focuses on the internal company information and external stakeholders' experiences by evaluating the digital asset, product information management, and data quality.

FIGURE 25

MAJOR SUCCESS FACTORS FOR THE DIGITAL INNOVATION PROCESS ROADMAP.



Source: Lin-Ya Hong, National Expert, ROC, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

FIGURE 26

RELEVANCE OF THE MAJOR SUCCESS FACTORS DURING THE IMPLEMENTATION OF THE DIGITAL INNOVATION PROCESS.

		Stage 1	Stage 2	Stage 3	Stage 4
Digital Innovation Process		Digital leadership appointed and strategy developed (core members)	Digital awareness through workshop and training (whole company)	Digital innovation collaboration	Outcome evaluation
Four major parts of roadmap during the digital innovation process: the enterprise defines each step and action plan during the digital transformation stage					
People	Key stakeholders in the ecosystem	People management and engagement process			
Process	Customer experience and digital marketing strategy	Customer experience design, customer relationship management, customer support platform, new customer and business model Digital marketing strategy and campaign			
	Order fulfillment and dispatch	Warehouse automation			
	Products and automation	Production automation, business process automation			
Technology	Data analytics and data management	Information security risk assessment → information security management	Data and information architecture, data analytics		
	Cloud service	Cloud platform implemented and restructured			
Content	Internal and external information content	Optimized content management (digital asset management, product information management, data quality, and data governance)			

Source: Lin-Ya Hong, National Expert, ROC, Digital Innovation Process Guide: Handbook for Manufacturing SMEs.

Lessons learned: Prioritizing the selection of the digital technology based on the company's core capacity, human capital, and growth status by different stages requires assistance from experienced experts and professional entities to carry out the diagnosis and evaluation plan before kicking off the digital innovation project. In addition, the project has to be managed by a leader who has sufficient knowledge of the business and also sufficient experience as an IT project manager. The company also has to provide resources for the additional tasks generated by the digital innovation process and constantly update and communicate with its various key stakeholders to ensure a smooth transition.

9.2.5. Digitizing the Value Chain for High Performance

Background of the SME: EB manufacturer of automotive parts was established in 1965 and has 120 employees today. The company has more than 50 years of history and has been certified in ISO 14001, ISO TS-16949, and QS 9000. The ROC's automotive part industry is continuously facing a variety of challenges, including cost pressure, global competition, and market shifts. The company has implemented the automated manufacturing process before introducing the project of big data and analytics.

Reaction to the digital innovation process: After the rise of PR China, the ROC's manufacturing SMEs have faced more competitive challenges in the global market. At present, there is 15–30% tax on the ROC's auto industry exporting automotive parts and components to the ASEAN market, while PR China's export to the ASEAN market is less than 5%. Digital innovation has strengthened

the company's capability for customized production with room for price negotiation. In addition, the dynamic market conditions have increased the complexity of marketing and sales planning processes. The application of big data and analytics has enabled the company to better understand its customers and markets to increase brand awareness and market-segment share.

Key actions the SME will take after having gone through the *Digital Innovation Canvas*: Since the recruitment of digital talent with related industry background is a challenge, the company is planning to establish an appropriate mechanism with vocational or technical universities to strengthen the talent recruitment and development process. It takes about seven years to develop talent: four to five years for technicians, three years for manufacturing-management talent, and one to two years for basic quality personnel in the automotive part industry.

Lessons learned: Automated production uses advanced quality and safety analytics that allow quality issues to be detected and resolved at an early stage. This improves the capabilities in quality management and also lowers the costs. However, when the company applied the digital innovation technology in the organization, the changes and transformation during the digital innovation process actually affected the management, operational, and manufacturing processes, and caused some interruptions and inconveniences to the existing project and order. The company has prepared the employees to face the potential problems they may experience before starting the project. In addition, it is also important to facilitate interactions among the supplier networks, partners, and customers in order to provide added value to all participants in the digital innovation ecosystem.

9.3. Case Examples from Singapore

From the more than 15 manufacturing SMEs that have been approached for the testing of the DIPG and the *Digital Innovation Canvas* in Singapore, a selection is presented in Table 20, highlighting the highly diverse areas of digital innovation in manufacturing SMEs. The following cases have been provided by Dr. Ahmad Magad, National Expert, Singapore. The first five cases listed in Table 20 are described in detail below.

TABLE 20

LIST OF SMEs FROM SINGAPORE PARTICIPATING IN THE TEST OF THE DIGITAL INNOVATION CANVAS AND THE DIGITAL INNOVATION PROCESS.

Case no.	Industry	Year of establish-ment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
1	Confec-tionery	2009	11	25	Introduction of basic I4.0 solution including training integrating produc-tion, administrative processes, and online order system	100,000	B2C
2	Power transmis-sion	1995	25	48	Integration of ERP system with online monitoring of production and shop-floor perfor-mance; enhancing cybersecurity	85,000	B2B

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Case no.	Industry	Year of establishment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
3	Vending machine manufacturing	2015	5	36	Digitalizing the replenishing process in vending machines via cloud-based IT system; AI for prioritizing and replenishing the vending machines	95,000	B2B
4	Optical equipment	1998	22	85	Integrating SRM into the ERP system	65,000	B2B
5	Personal mobility device	2016	4	40	Digital marketing: launch of campaigns via online platforms	48,000	B2B, B2C
6	Chocolate manufacturing	2011	9	16	Industry 4.0	75,000	B2B
7	Fiber packaging	2014	6	25	Automation, digitalization of additional product lines	100,000	B2B
8	Food manufacturing	2000	20	25	Digitalization of administrative processes and production, and inventory control; automation of production line; integration of ERP system with online monitoring of production and shop-floor performance; and enhancing cybersecurity	100,000	B2C
9	Engineering job shop	1995	25	52	Digitalization of entire manufacturing operations	80,000	B2B
10	Gift items	2005	15	19	Automating and digitalizing its assembly line to obtain real-time information	50,000	B2B and B2C
11	Engineering services for oil and gas industries	2002	18	60	Establishing 'factory of the future' with digitalization of its administrative and manufacturing operations	100,000	B2B

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Case no.	Industry	Year of establish-ment	History (years)	Number of employees	Digital innovation	Investment in USD	Customers
12	Livestock and packag-ing	2010	10	28	Moving into new factory premises with digitalization and smart logistics	120,000	B2B
13	House-hold/ kitchen hardware	1998	22	22	Digitalization of connectivity with customers and suppliers including web-based brand-ing and marketing	75,000	B2B, B2C
14	Micro compo-nents for telecom industry	2017	3	12	Improvement of communication along the supply chain during COVID-19; ERP system for automa-tion of production and inventory control; installing smart boxes to draw real date from the equipment	110,000	B2B, B2C
15	Precision compo-nents for aerospace industry	2012	8	22	Sensorizing all manufacturing equipment com-plete with real-time data and informa-tion output and digital display	80,000	B2B
...							

9.3.1. Striving to operate a 'Futuristic Factory' in a Traditional Industry

The confectionary company is an SME founded by a sole proprietor in 2009. He started the business with his wife and son assisting him, initially producing breads and selling them directly to customers with a counter in front of his shop. The business grew quickly by word of mouth. The founder decided to expand it by taking a larger space on rent and buying more modern automated equipment to increase his production capacity. The company now has 16 employees. His family and he run the administration of the business while the rest of the employees are production workers. Beyond bread, the operation currently manufactures cakes, various types of pastries, and tarts for B2B distribution and also for direct sales through his original shop.

Recognizing that automated equipment enables higher efficiency and consistent quality, his business expansion is predicated on investments in high-quality automation equipment. The founder has meanwhile also learned that going digital will enable him to gain even higher efficiency through better real-time connectivity between his production floor and administration, as well as linking with his online ordering system. Hence, the intervention of the SMF proposing to go through the DIPG with him was timely. SMF's business advisors went through the *Digital Innovation Canvas* with him so that he could understand the wider benefits in incorporating digitalization in his manufacturing and administrative processes. He became more interested to

pursue digitalization in greater depth, including putting in additional investments in capital and software to the tune of USD100,000.

Apart from a simple automated payroll and accounting system and an online ordering system, the founder has no digitalization experience on the shop floor. While the manufacturing equipment are automated and semi-automated, they are independent of each other and require individual workers to man them. Although the absence of digitalization experience represents a major barrier, the founder expressed keenness to learn and go through the process to fulfill his dream of operating a 'futuristic factory' and subsequently embrace Industry 4.0.

The SMF's business advisors were excited, and for a start, recommended a government-funded scheme through a preapproved solution provider. The generous scheme funds 80% of the cost of USD35,000, which includes the installations of IoT sensors and devices, digital chatbots, digital reports, and absorption of installation costs to enable him to get started with smart manufacturing.

A plan is being drafted currently for his next steps of digital transformation in conjunction with business growth projections.

9.3.2. Power Transmission Manufacturer Embarking on Industry 4.0

The company, founded in 1995 with about 50 employees currently, is an established engineering and power transmission manufacturer and a specialist. It has a relatively large and automated machine shop, equipped with robots and with a part of its operations already digitalized. Many production and support equipment are fitted with sensors, actuators, and IoT devices to enable data collection from the equipment on a real-time basis. Its customers are both local and regional. The company is planning to expand its operations to Japan, Europe, and the USA. During its formative years at the turn of the century, it employed a foreign expert to help automate its operations. After three years, the management was able to sustain its progressive development on its own, and more recently, decided to embark on Industry 4.0.

The SMF's offer to administer the DIPG and spend a few days to go over the *Digital Innovation Canvas* was welcomed with open arms by the SME as it was on the verge of embracing more in-depth digitalization and Industry 4.0. The SME also wanted to integrate its ERP system with the online monitoring of its production and shop floor's performance parameters, along with increased data analytics to have a better overview of real-time business information. As the systems converge, it also wanted to enhance the cybersecurity of the overall system.

Almost a full week was spent with the SME, involving senior BAs and a consultant to address the challenges that the management foresaw in digitalization and Industry 4.0, integrating the ERP system, and improving real-time information through better data analytics. The two-person IT team and the finance team were involved in substantial discussions with the consultant and were ultimately convinced that efficiency gained in managing information and analytics through cloud, and the real-time efficiencies to be gained, will far outweigh the inefficiencies of magnetic storage across six servers.

At the operations level, the company's employees were generally already conversant with digitalization as they progressively automated their operations over the years. However, most of the data were spread across six physical servers. They saw the merits of migrating to the cloud platform but did not know how to execute it. Concerns about downtimes and data losses, staff

competencies to manage the more sophisticated systems, and ensuring business continuity in the more digitalized operations were taken into account during the implementation. The management's confidence in the proposed solutions, such as migration to cloud solutions and systems integration, was won by bringing in experts with the required implementation experience.

9.3.3. Vending Machine Manufacturer Creating Impact from AI

The company, founded in 2015 with about 35 staff members today, is a manufacturer and distributor of vending machines that dispense beverages to consumers. As part of its innovation in response to customer suggestions, the company had installed conveyor belts to automatically load the beverages into the vending machines. The results were:

- increased and faster availability of the preferred beverages; and
- reduced loading time and labor costs, and increased sales.

Encouraged by the growth in sales from the innovation and in his endeavor to increase customer satisfaction, the company's managing director evaluated the development of an internal cloud-based IT system that supports data analytics, intelligently prioritizes the vending machines for beverage replenishment, and also automatically identifies locations of vending machines that are due for maintenance.

The managing director and his management team were aware of the latest technologies by attending exhibitions and seminars and were keen to modernize and increase the efficiency of their operations. To justify the upgrades, his business case for digital innovation was based on the return on IT investment from the increased sales of the beverages that the company would achieve. By digitalizing its replenishing process, it could better the turnaround time of the beverages and simultaneously strengthen its digital ecosystem. By integrating the shop owners and space providers at various locations into the digital replenishment processes, it would increase their revenues, and at the same time, decrease the switching cost for these customers.

As a second step, the company could also invest the surplus from the additional sales in the development of a fully automated beverage vending machine that incorporates a storage area. This would enable automatic replenishment and more efficient communication with the beverage delivery service and the beverage company.

Being relatively digitally savvy, the organization's management wanted to quickly migrate to the cloud-based IT system and incorporate the AI part that could intelligently prioritize the vending machines for beverage replenishment and also automatically identify the locations of vending machines due for maintenance.

The BAs feared that undertaking both projects together would be quite a monumental task that would require quite a lot of management time. So, they advised to break it into two separate projects. The management team agreed after much persuasion and were glad they did so after going through the experience of implementing the first phase, which took quite a bit of their time and longer than they initially envisioned.

During the migration of the IT system to the cloud, it was discovered that the inventory data of their vending machine parts were stored in a different server, which contributed to some data

access problems after initial migration. The consultant had to be called back to properly migrate the inventory data into the cloud system. This resulted in an additional 2 days of user acceptance testing of the system. The management was a bit unhappy but had to accept the fact that they overlooked the separate storage of inventory data. There were also concerns expressed after 6 weeks of migration to the cloud about a power failure that caused loss of data and information. An IT consultant was quickly roped in to retrieve the data and information and restore it back into the system. Confidence in the implementation process was also quickly restored.

When discussing the AI feature that would enable the system to intelligently identify and queue vending machines for beverage replenishment and automatic identification of locations of machines in need of maintenance, the management wanted the process to be done in a week, which was an unrealistic expectation. The AI specialist almost gave up. A third AI specialist had to be roped in to explain to the management that additional machine learning process and AI programming would take time and it was not possible to be done within a week as initially insisted by the management. This points to the need to have BAs and consultants who are thoroughly conversant and have the appropriate expertise in their respective fields. The management was finally convinced that incorporating an AI feature was not a matter of simple programming but involved several steps to make the system heuristic.

9.3.4. Optical Equipment Manufacturer Doing Digital Innovation for Securing Business in a More Diversified International Supply Chain

Established in 1998 with 85 employees today, UC Optics has developed a strong reputation as a supplier of high-quality precision optics and optical assemblies for projection and video applications, both regionally and internationally. It manufactures the optical lenses inhouse but purchases its optical glasses, molded glass blanks, production supplies, and precision metal components from various countries, especially from PR China. As such, it has quite a complex supply chain in the region involving various locations in PR China.

When PR China first imposed a lockdown at the onset of the COVID-19 crisis, its supply chain was severely disrupted. Wuhan was incidentally the ‘Optics Valley’ of PR China, where much of its raw materials and production supplies come from. The factories there were forced to shut down and nothing was allowed to get in and out of Wuhan. UC Optics’ supply chain was in disarray as they had not diversified adequately.

The general manager was devastated as he had delivery commitments to fulfill, especially to its customers in Europe and Japan. It dawned upon him that this was likely to be a long-drawn crisis and that he had to adopt agile ways of working to overcome the challenges being faced. He realized that he had no choice but to transform his supply chain rapidly to salvage his business. He had to very quickly work with suppliers in the region to secure new supply sources of virtually everything for his operation. Considering the much larger amount of data and information that he now had to deal with, he decided that the best way forward was also to build an agile and AI-driven supply chain with smart features, such as demand-sensing intelligence, localization and product flow optimization, and smart diversification.

While the general manager had good ideas about digitalizing and transforming the supply chain, he was confronted with a number of obstacles. These included

- finding and negotiating with new suppliers in various countries (it got progressively more challenging as the pandemic situation worsened);

- having new suppliers go through a qualification process, as a few of UC Optics' customers are high-end MNCs in Europe and Japan; and

- transforming the supply chain to make it more intelligent, data driven, and powered by technology, so that it was capable of predictive and prescriptive analytics to make insights and foresights more readily available within his organization.

SMF's senior advisors and the SME's leadership spent three full days with the manager to go over the *Digital Innovation Canvas* and the DIPG and assisted him with some ideas in his supply-chain transformation consideration.

Components like metal parts were quite easy to substitute with local suppliers, but items such as optical glasses, polishing compounds, and diamond impregnated generating tools were more difficult and had to be sourced from high-cost suppliers in Japan and Germany. The company's ERP system, which contains databases of all its worldwide key suppliers, came in handy to quickly connect back with the former suppliers from Japan and Germany. Higher cost was an issue, but the company had no choice but to incur it under such circumstances. The manager was quite pleased that he could leverage his ERP system to get the information he needed for alternative supply sources.

Qualifying new suppliers would typically require QA engineers to be present at the suppliers' facilities during the qualification process. This was not possible after the COVID-19 crisis worsened. It had to be resolved through technological means. SMF's business advisors recommended that a supplier relationship management (SRM) module be incorporated in the ERP system, with a product qualification feature in it. This would enable real-time direct links between QA engineers and the suppliers. Initial training on this module was focused on the product qualification feature so that they could quickly qualify new suppliers. Being determined to keep the customers, the manager proceeded with the investment in the module, which provided him with greater real-time supply chain control of his suppliers. The SRM module contains many features, such as supply chain management, supplier management, supplier performance management, and several analytical platforms. The BAs recommended a phased approach in embracing the module, with a view to first achieving the optimal performance requirements and later moving on to the analytics and intelligent parts. The management team agreed with the proposed plan.

As the pandemic worsened and most countries got into lockdowns, the company had no choice but to conduct all discussions with its stakeholders virtually. Owing to some sensitive elements of the business, the BAs recommended the use of Microsoft Teams as it was considered to be a secure conferencing and tele-commuting platform. Although face-to-face meetings were preferred, the management had no choice but to embrace the virtual platform due to the changed environment.

The AI feature, which would include, among others, demand-sensing intelligence, material flow optimization, and just-in-time deliveries, is still being discussed. Also, owing to the high cost of implementation, funding is being sought from government agencies. SMF's SME Centre's senior BAs and consultants are involved in the exhaustive discussion process. Advice has also been given for some of the key staff to be equipped with machine learning and AI skills as well as the knowledge to prepare for the next phase of implementation. Senior management is directly involved in key discussions at this juncture.

9.3.5. Personal Mobility Device Manufacturer Enabling Digital Innovation in Marketing Function

S-Scooters, established in 2016, is a relatively fast-growing SME that was set up to take advantage of the rapidly growing popularity and increasing demand for personal mobility devices (PMDs),

especially among young people for recreational activities. It currently employs 40 people, with most of them involved in assembling the devices, which recently reached a volume of 600 units per month, spread across three different models. Most of the PMD components are sourced from both local as well as overseas suppliers.

The SMF's SME Centre approached the company for the DIPG and digital innovation processes in the midst of the lockdown period when its production had slowed down to less than half of the capacity due to a drop in demand owing to the stay-at-home requirement. The management was nevertheless optimistic that the situation would change soon, and that demand would pick up to normal levels and beyond once the lockdown got lifted.

Throughout the DIPG process, the general manager expressed optimism on the growth of his business and demonstrated keenness to embark on the digital marketing platform as a means to rev up demand for his PMD products. The involved business advisor was knowledgeable in this topic and was able to provide sound advice, which further enthused the general manager to move to this platform as quickly as possible. A digital marketing agency was also contacted to assist in the process.

Although generally digitally savvy, the general manager and his two managers have no familiarity with digital marketing. His challenges with respect to expanding the business are:

- lack of knowledge in using digital techniques in sales and marketing to expand his business;
- lack of time as an inhibiting factor (as is the case with most SMEs) because the management is intensely engaged with other aspects of the business, especially paying attention to and ramping up production; and
- intense competition due to imports from neighboring ASEAN countries, especially PR China.

Notwithstanding the lockdown period, S-Scooters was also confronted with falling demand and intense competition from foreign imports. The general manager strongly felt that he needed an additional and more aggressive platform to defend his market share, win more sales, and compete with the foreign imports. The engagement with SMF to go over the DIPG with the company was timely, to take advantage of the lull period as well as familiarizing the management with the concepts and advantages of digital marketing.

The general manager and his management team were pleased that they were approached by SMF's SME Centre on a timely basis to help review their overall digital innovation strategies, especially on how they could grow their business by employing digital technologies.

Through the DIPG process, they were exposed to various digital marketing techniques such as:

- e-mail marketing;
- e-commerce and content marketing;
- search engine optimization;
- social media marketing; and
- campaigns on marketplaces such as Google and Amazon.

SMF BAs and the consultant went over each of the digital marketing techniques, their prospective impacts, the costs and timeline associated with each, and the combinations of the techniques and their respective advantages. As the general manager is intent on growing his business, he decided to try out two approaches, more so that part of the cost may be defrayed by government grants.

Being conversant now with the theoretical aspects of digital marketing, the next challenge was to choose the initial focus areas of digital marketing and their implementation. After a week of going over the DIPG, more meetings were held between the BAs, consultants, and S-Scooter's management. It was decided that campaigns on Google, Amazon, and Lazada be launched on different devices and on different advertising platforms. S-Scooter's management accepted the recommendation on the basis of the consultants' case studies and demonstration of past clients' successes.

The digital marketing campaign was revisited in early July 2020 to assess the success rate. It was discovered that some advertisements did not yield the desired results. Product ads that users would see when they searched for a competitor, especially those of established brands, yielded the best results. The consultants advised that ineffective ads from some channels be removed while those that gave the desired RoIs be retained and their frequencies increased.

The management was also briefed on cross-channel paid campaigns on YouTube, Facebook, and Twitter. Although the full desired effect of digital marketing is not seen yet, the management understands that it is still in its initial launch stage and are confident that it will get better with the passage of time.

9.4. Case Examples from Vietnam

From more than 30 manufacturing SMEs that have been involved in the testing of the DIPG and the *Digital Innovation Canvas* in Vietnam, 15 have been presented in Table 21, highlighting the highly diverse areas of digital innovation among manufacturing SMEs. For the first five listed companies, their brief descriptions are provided below, covering the digital innovations that the companies will pursue as a result of completing the *Digital Innovation Canvas*.

TABLE 21

SELECTED CASE EXAMPLES FROM MORE THAN 15 SMEs IN VIETNAM APPROACHED FOR THE TEST OF THE DIPG.

Case no.	Industry	Year of establish-ment	History (years)	Number of employees	Digital innova-tion	Investment in USD	Customers
1	Precision mechanical manufacturing (automobile parts, molds)	2005	15	200	Machine to machine communication	100,000	B2B
2	Mechanical manufacturing (conveyors, rollers)	2011	9	100	Automation of warehouse process	20,000	B2B

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Case no.	Industry	Year of establish-ment	History (years)	Number of employees	Digital innova-tion	Investment in USD	Customers
3	Beverages, drinking water	2016	4	~100	Apply robot in picking product to pallet and automatic pallet wrapping machine	52,000	B2C
4	Confectionary	2001	19	200	Automation of sorting and transferring products from production lines to warehouse	70,000	B2C
5	Lighting product (LED bulbs, lamps)	1961	60	250	Automation of loading products on the truck	15,000	B2C
6	Electricity cabinets	2013	7	220	ERP	50,000	B2B
7	Automated machine fabrication	2004	16	150	Virtual visit of customer to facility	10,000	B2B
8	Medical devices	2019	01	150	Online monitor-ing of produc-tion line	30,000	B2B
9	Precision mechanical (mold and die)	2013	7	280	ERP	70,000	B2B
10	Pharmaceutical products	1995	25	250	ERP	Under planning	B2B
11	Rubber tire	1980	20	300	Automation of warehouse process	20,000	B2B
12	Animal foods	2018	2	90	Digital com-merce and online technical service	10,000	B2B and B2C
13	Printing	2004	16	160	ERP	Under planning	B2B
14	Textile yarn	2019	1	200	ERP	Under planning	B2B
15	Electric wires and cables	1984	36	300	Automation warehouse process	Under planning	B2B
...							

9.4.1. Solution for a Mold and Pression Metal Parts Manufacturer for Monitoring Productivity Data and Report in Real Time

The company was established in May 2005 for manufacturing molds and pression metal parts. Now it has 200 employees. After 15 years of development, the company has become a partner for leading manufacturing companies in the fields of motorcycles, automobiles, and household appliances. The company strives to measure and reflect value by visualizing the processes,

standards, and achievements for easily recognizing all problems. It believes that sufficient and accessible information systems help employees work more effectively.

Although the company has applied lean manufacturing approaches in production management, productivity data in some stages are still collected manually, which leads to longer time in collecting, analyzing, and taking corrective actions. As a result, defective product quantity is rather high. Therefore, the company was looking for a solution to monitor productivity data and be able to report it in real time.

The company was introduced to the *Digital Innovation Canvas*. Throughout the workshop on developing the canvas, the management team identified IoT as a key solution to help them address their need. In addition, they took machine-to-machine communication as a further measure of innovation in production management. The company started to search for a technology provider to further assess the solution and to plan investment for that in its next year's budget.

9.4.2. Automated Warehousing Solution for Reducing Storage Space Demand and Improving Inventory Management

A manufacturer of customized conveyors, rollers, and automated systems of packaging and sorting, established in 2011, has 100 employees today. Along with an increasing customer demand, the organization faced limitation in their storage space and long lead times for locating and taking components from the warehouse. Also, the inventory data was difficult to manage and update.

The company was introduced to the *Digital Innovation Canvas*. During the workshop on developing the canvas, the management team identified automated warehousing as a solution to improve its warehouse management. This helped increasing the vertical storage space and automating the receipt and issuing process, as well as updating the inventory data.

The company has started to assess technology solutions and plans for investment in the next years.

9.4.3. Introducing Robots in a Beverage and Bottled Mineral Water Company

Established in July 2016, the company specialized in manufacturing of nonalcoholic beverages and mineral water. Today they have 100 employees.

The mineral water is filled in 20-liter bottles, which are loaded manually on pallets. Often, bottles get dropped, which damages the product and causes injury to the operator. Also, pallet-wrapping is done manually, which again turns out to be an unstable process that often leads to low quality of the wrapping.

The company was introduced to the *Digital Innovation Canvas*. During the workshop on developing the canvas, the management team identified the benefits of using a robot for loading the product to the pallet and of an automatic pallet-wrapping machine.

The company started to look for a technical provider and wants to implement the solution as soon as possible.

9.4.4. Introducing Automation in Key Processes at Well-known Confectionery Manufacturer

The company is a well-known confectionery manufacturer in Vietnam, established in 2001. Now it has around 200 employees.

Due to the nature of the product, the quantity varies batch by batch. This makes it difficult to manage the quantity of final products in each box. Furthermore, the final products are taken manually by forklift to the warehouse which is located 100 meters away from the production site.

The company was introduced to the *Digital Innovation Canvas*. In the workshop on developing the canvas, the management team identified a digital solution for their issues in the form of automated sorting and transportation to the warehouse. Each product that runs from the box packaging line will pass by a barcode camera to identify the product code. Then, the product will go on an online scale for automated checking of the weight of each box against the standard weight for the respective product code. If the weight is right, then the box will go on the conveyor belt to the warehouse. If the weight is not right, it will automatically be taken to the rejection area. The data of the product sent to the warehouse will automatically be updated via the software connected to the barcode camera system. This software can also synchronize with the company's ERP system.

The company started to look for a technical solution provider and apply the solution as soon as possible.

9.4.5. Introducing Automation in the Loading Process of a Manufacturer of Lighting Products and Developing a Digital Transformation Strategy

The company was established in 1961. Now it has around 250 employees. It manufactures various lighting products resulting in a high number of stock-keeping units (SKUs). Loading the products from warehouse to the trucks/containers is done manually. Due to that, selection of wrong quantity and wrong SKU happens. Given that the products are fragile, manual picking of the lighting products frequently result in damage of the products.

The company was introduced to the *Digital Innovation Canvas*. During the workshop on developing the canvas, the management team identified an automation solution for loading the products to the trucks, integrated with a barcode camera for checking the SKUs. The data could then be collected electronically and used for tracking purposes. The company started to look for a technical solution provider and would like to apply the solution as soon as possible. The company also developed an overall digital transformation strategy including smart factory 4.0 features and manufacturing of smart LED lighting products.

9.5. Case Examples from Europe

There are numerous case examples available from an EU-funded project with focus on ICT-enabled Innovation for Manufacturing SMEs (I4MS). With the support of digital innovation hubs across Europe, SMEs across Europe were assisted to accelerate their digital transformation [11].

The following examples from manufacturing SMEs based in Europe highlight the digital innovation journey that many of these companies have undertaken during the past years and the benefits they have gained. In all cases, this journey has not come to an end. It has taught the organization how to build on their achievements in digital innovation and how to further leverage them to better serve their customers in future as well.

9.5.1. Making Collapsible Plastic Boxes Smart

A 40-year-old SME [12] with about 150 employees manufactures foldable plastic boxes used in industry and retail. With modern logistics, the integration of the boxes into the smart factories' inbound logistics required the boxes to be compatible with ground-mounted hoisting machines.

The boxes have to be suitable for different goods ranging from food to electronics, be compatible with the customers' conveyor belts, become smart, and hence be highly customizable to meet specific customer requirements. Therefore, the company started to use an auto-ID system (an RFID-ready version) for identification of the boxes in the customer's automatic system. This auto-ID system also facilitates tracking of the goods stored in the boxes.

High customization of the boxes usually requires longer development times whereas customers want to have the boxes as quickly as possible. The company overcame this challenge by using 3-D printing technology for their prototypes. This allows customers to test the prototype under 'real' conditions at their premises. At the same time, 3-D printing is also used for small batches. They can now be offered at competitive prices and within reasonable timeframes.

9.5.2. Leveraging Robots for High-precision Product Manufacturing

This market leader [12] in manufacturing of grinding and polishing machines for industries as diverse as automotive, surgical, tube, cutlery, and wood processing, among others, shifted from traditional technologies to CNC technologies and high automation. Since 1997, robotics has also come more and more in use. Depending on the customers' requirements, robots with four to six arms were used for the automation of grinding and polishing machines. Using robots is even more flexible and reliable than previous technologies. Robots fit the parts into the grinding or polishing machines. Based on opto-electronic data collected by more than 150 cameras, the robots communicate among themselves and decide autonomously which part will be processed in which sequence. They also know which picker arm to use for which part. Sensors provide the signals to the robots. To monitor the production, an app for smartphones and tablets has been developed to give access to various data that are important for the operator, e.g., for maintenance. In future, the aim is to have the machines start their maintenance autonomously.

9.5.3. Getting Ready for the Digital Future in the Food Value Chain

A family-owned business, manufacturing sea buckthorn products ranging from juice, jam, oil, liquor, and cosmetics, faced key customers' (retailers) requirements for consistent and coherent data about the products [13]. In the food supply chain, detailed data about the products, their origin, date of expiration, etc. had to be provided electronically. "Digital scales and meters which register all the quantities and deviations in real time and forward the data to the digital merchandise management system, first had to be tested in real-life conditions. In order to visualize the procedure before it was actually purchased, some prototypes were developed. Thus, the highly complex interrelationships could be identified and were easy to understand for the team. The collaboration succeeded in making the sea buckthorn factory's merchandise management system fit for the future" [13].

9.5.4. Taking a Step-wise Approach to Automation in the Food Business

A 100-year-old family-owned UK-based bakery, with about 200 employees, serves the northwest part of England with a fleet of 52 vans delivering to over 3,000 locations. To move from packaging the bakery goods by hand, the company decided to shift to semi-automated processes and "made a return on its £75,000 investment within a year" [14]. "This enabled the company to increase the throughput significantly. Before implementing the bag packaging system, the team could produce up to 2,500 packs of 12 tea cakes a day. A team of four could bag and label 200 packs of 12 tea cakes per hour. Today, they can pack twice as much in a bag, twice as fast, and with half the number of people, freeing up staff to concentrate on other aspects of the business such as quality control and customer service" [14].

9.5.5. Increasing Production by More than 15% with Automation of Production in Small Batch Manufacturing

The challenge of a Germany-based cardboard box manufacturer [12] with about 100 employees was the integration of small batches with high-volume heavy corrugated boxes while eliminating damage during inbound transportation and significantly reducing the delivery times. The company installed a ground-mounted hoisting system. With the digitalization of materials management, transport became much more efficient. Barcodes allow information about delivery dates in real time. Combined with the automated transportation of the necessary tools from the high rack, warehouse productivity has increased by 15–20%.

10. CHALLENGES TO BE MASTERED DURING DIGITAL INNOVATION

There are many potential challenges during the transformation into a digital innovation organization. These include

- general management challenges;
- financial challenge;
- technical challenge;
- cybersecurity challenge;
- supply chain challenge;
- business challenge;
- operational challenge; and
- infrastructural challenge.

Being aware of these challenges will help guide the SMEs effectively and increase the probability of their successful transformation into organizations whose sustainable growth is based on continued digital innovation in products, services, processes, systems, business models, culture, and networks.

10.1. General Management Challenges

Often underestimated are the cultural challenges that SME managers face. SMEs are often family-owned, so in these companies it is common practice to hand over positions to relatives regardless of the family member's capabilities. Collaborating with experienced specialists from outside, e.g., from academia and research institutes, can facilitate skills development and change in organizational culture towards a horizontal and agile management that is used to taking and sharing responsibility. Involving external experts in the digital innovation project, which usually bears some risks, will also foster learning how to assess, take, and manage these risks.

The skills and educational background of the company's employees matter in how digital technologies are applied and implemented. In order to effectively use digital technologies, the company needs to invest in complementary knowledge-based human capital for the organization's specific skills and knowhow. The priority is to develop qualified talent from internal skilled

workforce, while also screening and recruiting potential applicants from outside. The company also has to prepare for a future workforce that can analyze big data, develop applications, and manage complex database networks to respond to the increased need for automation and digitalization of operational processes. The company has to provide related training courses such as big data analytics, digital marketing, AI, social media, IoT, and e-commerce.

With progressing digital innovation in the organization, the SME management needs to empower their staff to take and share responsibility. This may start with setting up a project team for the next digital innovation project involving different functional department heads to work together on the digital innovation project. Thus, the expertise, knowledge from, and requirements of various departments will be adequately considered. Nevertheless, it is the SME's management that has to support the team and fully commit to the digital innovation journey that the company is taking.

10.2. Financial Challenge

Digital innovation requires financial investment in technologies, data protection, skills development, and skilled labor force. At the same time, digital innovation projects bear risks of failure. The failure might result from betting on the 'wrong' technology, from lack of compatibility with other systems and technologies, from wrong timing of the innovation's launch, or from too long a period to reach the breakeven point. The company not only has to consider the costs of the digital technologies, but also the associated investments to ensure a successful implementation and maintenance subsequently. These include the costs of related services and investments in training and process innovation. In many countries, SMEs can seek public funding and subsidy to access the use of digital technologies. Investing in a digitally skilled labor pool is a long-term investment to facilitate the successful implementation of a digital innovation process and the digital transformation of an organization.

10.3. Technical Challenge

Innovation-enabling technologies might increase the complexity of digital technologies and tools in an organization. They might also exceed the organization's capacity to master these technologies. As a result, the company becomes more dependent on external experts. Switching costs increase when a different technology becomes the industry standard. Some of the technologies might not have the level of maturity at the time they are implemented. Troubleshooting might become 'normal.' Therefore, SMEs might keep their existing technologies while also adopting the digital technology. This would carry the risk of increased complexity as well as of neglecting the new technology as the existing one still works.

10.4. Cybersecurity Challenge

With digital innovation, cybersecurity becomes a major challenge. Data protection becomes a challenge when more and more data are generated in the various process steps of procurement, manufacturing, marketing, and sales. For SMEs, it is a new experience to control the transfer of data to and from different devices and to protect the access to their digitized data. The challenge becomes even bigger when data is exchanged in the integrated systems within the supply chains/networks. Data security obligations have to be borne also by the SMEs. A first step might be to store the data in a professionally managed cloud. This has to be complemented with state-of-the-art data protection measures and training of the staff in data protection and cybersecurity risks.

10.5. Supply Network Challenge

By opting for specific digital technologies, SMEs take the risk that they will no longer be able to integrate their systems into (potential) customers' and suppliers' systems or to comply with different (safety) standards. The early-mover advantage might not exist for SMEs as they depend on the larger companies setting the standard for digital technologies within the supply network. Coping with different standards and technologies might exceed the SMEs' coordination and complexity management capacities. Yet, in many industries, SMEs as suppliers to larger organizations will have to integrate their systems into those of their large customers to allow the traceability of parts and products. During the transition phase from traditional to digital processes, the SMEs need to develop a transition plan that will secure their business continuity.

10.6. Business Challenge

A digital innovation, if it is new to the market and not just new to the firm, bears the risk of jeopardizing the entire business. Doing nothing might lead to the same effect. Therefore, the management should ask themselves: "What if a competitor brings this innovation to market? Would this put the existence of our organization at risk?" Digital innovation in core processes might also stretch the organization's ability to transform and key staff members might leave the company (loss of core competencies). Also, the management might not have the time and resources to drive both, 'business as usual' and 'the digital innovation project,' thus putting the existence of the company at risk. Although the return on investment in digital innovation is highly unpredictable with potential risk of loss, the company has to be aware that there is no alternative to digital innovation. The digital transformation process is a continuing long-term process. Therefore, setting a three-to-five-year goal for the return on investment is more realistic. The SMEs also have to take the intangible assets into account that they will develop during the transformation process.

10.7. Operational Challenge

Cost, complexity, and lack of technical and management skills are the main drivers of the operational challenge. Digital technologies usually become more costly than expected. External support will be required, e.g., for maintenance, regular updates and integration into other (external) systems. Managing the traditional business, while at the same time developing digital innovations, requires additional management skills and strong support from staff members. However, often the management lacks the understanding of the implications resulting from digital technologies and their business impact. Traditional SMEs might not have the staff with the (analytical) skills and motivation to transform the organization into a digital innovation champion. They might be overwhelmed by the complexity they have to master during the transformation of the organization.

10.8. Infrastructural Challenge

Infrastructural challenges result from lack of high-performance internet, and also from lack of education in advanced technologies and lack of confidence in the economic situation and development.

Continued availability and accessibility of power and high-speed internet, which are basic requirements, are not always available in all countries, especially in rural areas. SMEs in

developing countries need a strong lobby to mobilize the public authorities to invest in these infrastructural improvements.

Limited access to skilled labor is another 'infrastructural' challenge for SMEs. Well-educated graduates prefer working in well-known large corporations where salaries, on average, are higher. SMEs are not able to afford these candidates, thus limiting the organization's capacity for digital innovation. Initiatives on sectoral as well as regional basis have to be pushed to close the skills gap.

If the SME management is not convinced of the future development of their business, they might not invest in digital innovation at all. Here, examples might help that illustrate that even in tough times, investing in the future can pay off. This is the entrepreneurial skill needed to grow the business sustainably.

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12. GLOSSARY

The key terms and definitions used in this DIPG will be briefly explained to enable consistent understanding and usage.

Digitalization: "The use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business" [15].

Digitization: "Digitization is the process of changing from analog to digital form" [16].

Innovation: As per ISO 56000, it is a successfully commercialized new idea, "new or changed entity, realizing or redistributing value."

Innovation management: As per ISO 56000, it refers to coordinated activities to direct and control an organization with regards to innovation. SMEs require a clear innovation strategy; an innovation organization and culture that translates the strategic goals into action; the innovation life-cycle process, including idea management, development of the idea into an innovation, launch of the innovation, and its continuous improvement and phasing out in due time; the innovation-enabling factors such as human resources, IT systems, and knowledge management.

Smart manufacturing: It leverages advanced, mainly digital, technologies to respond or even anticipate customer demand by adjusting the manufacturing processes in real time to that demand and thus enhance the value for both the customer and the manufacturing organization. Introducing smart manufacturing has implications along the organization's value network.

Value network: "The context within which a firm competes and solves customers' problems [17]. (It is) the collection of upstream suppliers, downstream channels to market, and ancillary providers that support a common business model within an industry. When would-be disruptors enter into existing value networks, they must adapt their business models to conform to the value network and therefore fail at disruption because they become co-opted [18].

13. ABBREVIATIONS

AI	Artificial Intelligence
AIMS	Artificial Intelligent Manufacturing System Research Center, ROC
APO	Asian Productivity Organization
ASN	Advanced Shipment Notification
AVM	Audio Visual Marketing
BA	Business Advisor
B2B	Business to Business
B2C	Business to Consumers
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAPA	Corrective Action Preventive Action
CP/CPK	Process Capability/Process Capability Index
DIPG	*Digital Innovation Process Guide*
DM	Digital Marketing
ERP	Enterprise Resource Planning
FMEA	Failure Mode and Effects Analysis
IIoT	Industrial Internet of Things
IoT	Internet of Things
KPI	Key Performance Indicator
MES	Manufacturing Execution System
MSME	Micro, Small and Medium sized Enterprises
MNC	Multi National Corporation
MOST	Ministry of Science and Technology, ROC
OEE	Overall Equipment Efficiency
PCB	Printing Circuit Board
PDI	Pre-Delivery Inspection
PM	Predictive Maintenance
PMD	Personal Mobility Device
PLM	Product Life-cycle Management
PPM	Parts per Million
QA	Quality Assurance
QMS	Quality Management System
ROI	Return on Investment
SaaS	Software as a Service
SC	Supply Chain
SKU	Stock Keeping Unit
SME	Small and Medium-sized Enterprise
SMF	Singapore Manufacturing Federation
SPC	Statistical Process Control
SRM	Supplier Relationship Management

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HANDBOOK FOR MANUFACTURING SMEs