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Towards “Print 4.0” - To meet the challenges and opportunities in future for Hong Kong Printing Industry

Guidebook for Printing Industry

Contents

Editorial Board and Disclaimer

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1 Reader's Guide

This document introduces a systematic approach to Print 4.0 so that readers can comprehend the ideas behind Industry 4.0 and Print 4.0. The difficulties faced by Hong Kong's industries are highlighted in this study, which also explains the new opportunities that are being created. The session contained within the document are as follow:

Introduction – Project Background

This section provides an overview of the project, including the motivation behind it and its scope. It also introduces the entities involved in the project.

Introduction to Industry 4.0 & Print 4.0

An introduction to the concepts of Industry 4.0 and Print 4.0 in this section. It explains the correlation between industry 4.0 and print 4.0, as well as challenges and opportunities that Print 4.0 presents for the printing industry in Hong Kong.

Methodology

This section describes the assessment methodology for Print 4.0 employed in the project, including the print 4.0 navigator approaches and the print 4.0 maturity assessment methods.

Key Insight for the Printing Industry

This section presents the key insights consolidated from the research conducted in the project. It highlights the importance of digital processes and tools in the printing industry in Hong Kong and beyond.

Roadmap for the Printing Industry

This section illustrates a roadmap for the printing industry in Hong Kong to adopt Print 4.0. It provides guidance on the requirement for reaching each maturity level of Print 4.0.

Print 4.0 Use Cases and Applications

This section provides examples of use cases and applications of Print 4.0 in the printing industry. It describes the scenarios of each use case that can be achieved through the adoption of Print 4.0.

Functional Enablers

This section describes the functional enablers required to implement Print 4.0 successfully. The general workforce capabilities and overarching viewpoints are discussed.

Technology Landscape

This section provides an overview of the technology landscape in the printing industry. It discusses the different technologies available and how the printing industry can benefit from these technologies.

Vendor Landscape

This section provides an overview of the vendor landscape in the printing industry. It identifies the vendors' products and services, and their capabilities to drive Print 4.0.

Best Practices

This section presents best practices for the implementation of Print 4.0 in the printing industry. It provides guidance on the key factors to consider that leverage the enterprises to greater achievement.

Recommendations for Print 4.0 Implementation in Hong Kong

This section provides specific recommendations for the implementation of Print 4.0 in the printing industry in Hong Kong. It takes into account the characteristics of the printing industry in Hong Kong.

Comparison of Printing Industry in Germany and Hong Kong

This section compares the printing industry in Germany and Hong Kong. It highlights the differences between the two industries in terms of the implementation maturity of Print 4.0.

Self-Assessment Manual

A self-assessment tool is introduced in this session to help you evaluate your company's digital maturity index and plan investments in appropriate pilot projects. Self-assessment tool can be found on Print 4.0 website.

2 Introduction – Project Background

2.1 Motivation

The Print 4.0 initiative in Hong Kong was motivated by the challenges facing the printing industry, including the increasing costs, changing consumer behaviours, and environmental concerns. The industry has seen a shift in customer orders from a single mass production mode to a "high-mix, low-volume" mode. The market environment has also been evolving, driven by the progression of information technology and heightened transparency of information. These changes have presented diverse challenges to industries worldwide, including globalization, higher customer expectations regarding service and product quality, and the incessant advancement of production technology. Print 4.0 examines how Industry 4.0 has affected the printing sector as well as how its technology and concepts interact with cross-functional and inter-company printing operations.

The challenges facing the printing industry have made it imperative for businesses to embrace digitalization and strengthen their digital capabilities to remain competitive. Print 4.0 provides a roadmap for Hong Kong enterprises to transition to a more intelligent printing production process and improve their overall efficiency, collaboration, and transparency. The initiative aims to provide actionable recommendations for businesses to leverage the opportunities presented by Print 4.0 and achieve sustained success. By embracing digitalization and adopting new business models, companies can increase customer satisfaction, explore growth potential, and contribute to environmental sustainability. The Print 4.0 initiative is an essential step towards transforming the printing industry in Hong Kong and ensuring its long-term sustainability in a rapidly evolving market environment.

2.2 Project Scope

The Hong Kong Printers Association, in collaboration with the Hong Kong Productivity Council (HKPC) and foreign partners, launched the initiative "Towards Print 4.0 - to meet the challenges and opportunities in the future for the Hong Kong Printing Industry." The primary objective of this initiative is to assist Hong Kong Small and Medium-Sized Enterprises (HKSMEs) in implementing Print 4.0 and developing greater digital skills in the printing sector.

There are over 100 HKSME printers were surveyed on their printing services and processes in the three major project phases from 2020 to 2023. Additionally, a total of 15 pilot printing companies were evaluated to determine the status quo of production processes. Based on the insights gleaned from these evaluations, comprehensive roadmaps were developed to aid businesses in designing the transition to Print 4.0 and initiating value creation. Furthermore, international conference and

seminars were arranged to discuss Print 4.0's value, application domains, and business model developments.

2.3 Introduction of Entities

香港印刷業商會 THE HONG KONG PRINTERS ASSOCIATION	**Hong Kong Printers Association** Established in 1939, the Hong Kong Printers Association (HKPA) is one of the longest-history trade organizations in the HKSAR. It aims to promote the growth of the local printing industry, voice industry's opinions to the Government, assist members in business development, as well as enhance relationships of employers and employees in the industry. The Association has now maintained a membership of 400 companies, consisting of local printers, publishing companies and printing machine and material suppliers. The members include international corporations, HK-listed companies, active SMEs and senior members of the industry.
hkpc 生產力局	**Hong Kong Productivity Council (HKPC)** The Hong Kong Productivity Council (HKPC) is a multi-disciplinary organisation to promote excellence of productivity through continuously drive of advanced technologies and innovative services to support the local enterprises. HKPC strives to facilitate new industrialization in Hong Kong by offering comprehensive innovative solutions to local enterprises, and closely collaborating with local industries and world-class R&D institutes. The development of technological application solutions by the council has created values for a variety of sectors and brought enormous business opportunities ahead.

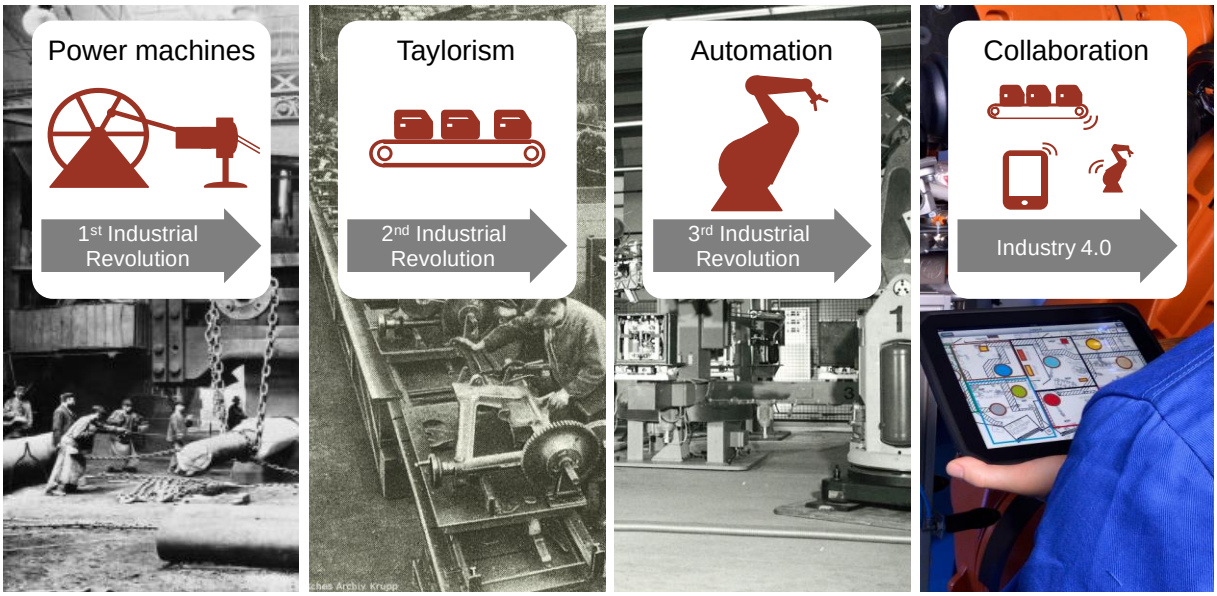
Fraunhofer IPT	**Fraunhofer IPT (Institute for Production Technology)** The Fraunhofer IPT is a research institute located in Aachen, Germany. It is part of the Fraunhofer Society, which is Europe's largest application-oriented research organisation. Focusing on innovative production technologies, processes and systems, the institute develops and optimises system solution for the networked, adaptive production of sustainable and resource-efficient products and the associated services that enable companies to leverage the benefits of Industry 4.0.
INC INVENTION CENTER	**INC Invention Center** INC Invention Center is a leading consulting and implementation service provider that offers profound expertise in Industry 4.0, AI in production, sustainability, innovation, and technology management. The center is a spin-off of Fraunhofer IPT and consolidates knowledge and resources from various Fraunhofer and research institutes. As an implementation agent in the Print 4.0 initiative, INC Invention Center collaborated with the Hong Kong Productivity Council to conduct cross-industry surveys, assess pilot companies, and develop actionable recommendations for Hong Kong businesses. The center's core competencies lie in its ability to assess the current status quo, analyze the challenges and opportunities, and develop comprehensive roadmaps to guide companies through their digital transformation journey.

3 Introduction to Print 4.0 & Industry 4.0

3.1 Industry 4.0

The production always plays an important role in any economy. In order to maintain the competitiveness and survive in a fast-changing market, adoption of quick manufacturing by an enterprise to minimize time-to-market, with best cost and quality. The industry must leverage themselves toward the fourth industrial revolution, or Industry 4.0, by take the advantage of data-driven operations.

The industry 4.0 composes a transformation of industrial value creation via flexible, dynamic, and seamless value networks. Industry 4.0 offers a data-oriented approach for enterprise to explore and capture the value, which enable the companies to become adaptive to the dynamic markets and quick changing environment by introducing data-driven business model, production, and services. Supported by mature information and communication technologies nowadays, Industry 4.0 enables companies to enhance the interconnectivity and interoperability along the value chain.



Technology Enablers of Industry 4.0

In the industry 4.0, the interconnection of people, system, and devices via Internet of Things (IoT) enables a real-time communication and information exchange between human and cyber-physical system. Single Source of Truth (SSOT) is one of the key assertions in data-driven operation to ensure data consistency and cleanliness along the value chain for data analytics application. Sensor technologies, ICT infrastructures, IoT mechanism, data analytic capabilities, and intelligent systems are the key enablers of industry 4.0 that can provide a data-based insight to users and bring extraordinary intelligence throughout the value chain.

3.2 Print 4.0

Print 4.0 refers to the connection and integration of Printing processes within and between enterprise and production facilities along the entire value chain for establishing a real-time decentralized printing network. The printing industry is substantially affected by the interconnectivity between people and cyber-physical system due to the evolution of the internet from a source of information to the Internet of Things and Services. Industry 4.0 technologies that are revolutionizing the printing industry include cloud-based printing services and intelligent printing equipment. Cloud-based printing services allow consumers to access printing services via the internet, without the need for local hardware or software. Smart printing equipment, on the other hand, consists of printers outfitted with sensors, connectivity, and sophisticated software that enables them to communicate with other machinery, devices, and systems.

The advantages of cloud-based printing services for print manufacturers and their clients are numerous. For instance, they can offer on-demand printing services, allowing consumers to print documents from any location. They can also provide secure and scalable printing solutions, allowing businesses to more efficiently manage their printing requirements. In addition, cloud-based printing services can assist printers in optimizing their printing processes, lowering their expenses, and increasing their profitability.

Smart printing apparatus, on the other hand, can assist printers in real-time monitoring and control of their printing processes. For instance, they can provide information on ink levels, paper usage, and printer performance, allowing businesses to optimize printing workflows and reduce waste. Additionally, they can facilitate remote diagnostics and preventive maintenance, thereby reducing downtime and maintenance expenses.

In addition, intelligent printing equipment can integrate with other systems and devices, such as cloud-based printing services, to establish a connected printing ecosystem. This allows businesses to more effectively manage their printing processes, from design and prepress to completion and distribution.

Cloud-based printing services and intelligent printing equipment are examples of how Industry 4.0 technologies are empowering print manufacturers to transform their operations, increase their efficiency, and boost customer satisfaction. By leveraging the power of the cloud and connectivity, print manufacturers are able to provide customers with innovative and adaptable printing solutions. In addition, by utilizing smart printing equipment that can monitor and control printing processes in real-time, print manufacturers can optimize their workflows, reduce costs, and enhance sustainability. By implementing cloud-based printing services and intelligent printing equipment, print manufacturers can remain competitive in a market environment that is becoming increasingly digital and dynamic,

while also meeting the changing needs of their customers. Print 4.0 is not only about developing a digital value chain for individual companies, but also about a collaborative value chain network of companies from all around the world.

Digitalization enables the printing industry moves toward an interactive, innovative and flexible business model and partner networks. All individual assets, goods, system, as well as other network elements and entities are able to communicate and collaborate over the internet. With a smartphone or tablet on hand, human can already contribute data to the network, for instance, equipment maintenance, automated quality inspection and AGVs control via warehouse.

Benefits of Print 4.0

The objectives of Print 4.0 are the horizontal and vertical value networks optimization and automation of material flows and resource use. Print 4.0 delivers value for businesses in the following ways:

1. Excellence of Deliverables

Through end-to-end tracking of things and assets, forecasting of bottlenecks and delays, and identification of risks, delivery reliability is improved. Through condition monitoring of goods and real-time process monitoring, higher-quality printing goods and services are generated. The capacity to adapt to unpredictability and propose alternative courses of action or scenarios may enhance adaptation.

2. Information Transparency

The absolute transparency generated by the integration of entities and production processes along the whole value chain facilitates manufacturing management and decision making.

3. Smart Operation

As digitalisation and connection advance, partial or total automation of TA becomes feasible. For example, robotic process automation (RPA) can assist or fully automate processes or workflows, or cargo could become intelligent and coordinate its own autonomous transit.

4. Enhancement of Enterprise Collaboration

The interconnectedness of enterprises along the value chain enables more effective labour division and collaboration with partners, suppliers, and customers.

5. Innovative and Agile Business Model

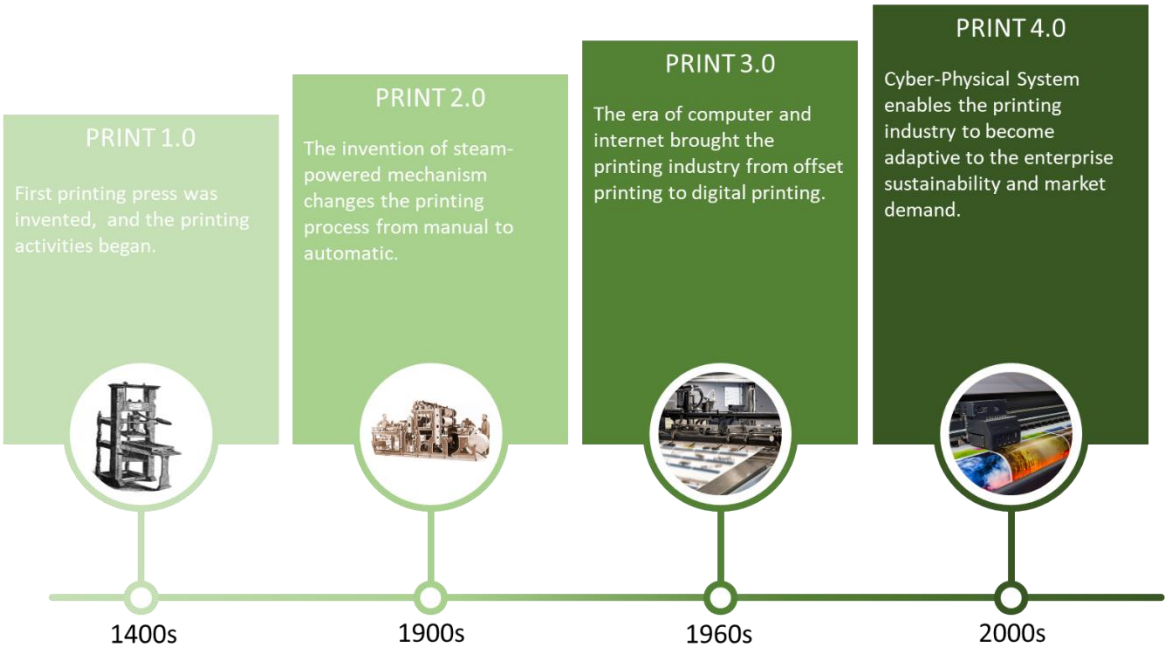
Massive data gathering throughout the value chain enables information-driven and platform-based business models with new revenue and service delivery models, such as cloud-based printing, encrypted online printing platform.

6. Sustainability

There is growing awareness and concern about sustainability and the environmental impact of manufacturing processes. Industry 4.0 technologies can help print manufacturers to reduce their environmental impact by optimizing their energy consumption, reducing waste, and using eco-friendly materials.

Evolution from Print 1.0 to Print 4.0

Impressed by China's movable type printing, the Europeans invented their metal movable types and the first printing press in the 15th century. The European later invented the steam-powered rotary printing press in the 19th century, which was revolting the printing activities at that moment. Ushering the third evolution of printing began in the late 20th century with the advent of digital technologies, which transformed the printing industry into a digital approach. Different printing methods were developed, for instance, dot mix printing, laser printing, and ink printing.



The fourth revolution of printing requires the building of a network among all human activities and digital events together with the printing process. The technology enablers of Industry 4.0, such as the Internet of Things, big data, and artificial intelligence, can enable a data-driven operation in the

printing industry and create value along the value chain. The printing industry must embrace digitalization and enhance its digital capabilities to remain competitive in a market environment characterized by globalization, higher customer expectations, and the incessant advancement of production technology. Print 4.0 offers a roadmap for Hong Kong companies to transition to a more digitalized printing production process and improve their efficiency, collaboration, and transparency, thereby achieving sustained success in the fourth revolution of printing.

3.3 Challenges and Opportunities of Print 4.0 for Hong Kong

Observed challenges in Print 4.0 for Hong Kong SMEs

During the visits of the selected pilot companies, various challenges in the general context of Printing and for the introduction of Print 4.0 were observed:

Rapidly Changing markets and customer demands

Currently the top challenges faced by most companies is changing markets and customer demands. Customers demand for shorter lead times, growing product diversity with smaller lot sizes makes it very difficult for companies to handle the processes and making sure delivery deadlines are met. Management sees this as a top priority in most companies

Heavy Rely on Manual adjustment on the plan

Planning is also a major topic as most of the companies rely on manual adjustment of the plan by the experienced planners. Planning is either done through excel or sometimes use ERP process, but this setting is not capable of managing planning rules and restrictions and need manual iterations which is time consuming.

Utilization of classic and manual communication methods

There are lots of manual and paper-based processes seen leading to media breaks. ERP systems are mainly used for commercial processes. Examples of commercial processes that can be managed by ERP systems include:

Sales and Marketing: ERP systems can help manage the entire sales process, from lead generation to closing deals. They can also provide insights into customer behavior and preferences, enabling businesses to develop targeted marketing campaigns.

Procurement: ERP systems can help printing company manage their purchasing process, from supplier selection to payment. They can also provide real-time inventory management, ensuring that businesses have the right amount of stock on hand to meet customer demand.

Inventory Management: ERP systems can help factory manage their inventory levels, track their stock movements, and optimize their supply chain. They can also provide real-time data on inventory levels, enabling businesses to make informed decisions about purchasing and production.

Few companies have developed advanced ERP are seen inhouse, but they still miss a lot of functionalities. Shopfloors are mainly managed with paper documents.

Impeding Data-based Improvement Processes

Gathering data from the shop floor poses difficulties due to the fact that not all machines are digital or connected, and some may use proprietary protocols or data. This results in a shortage of data-driven improvement processes, such as maintenance and quality logs, and supplier reviews.

Opportunities of Print 4.0 for companies in the GBA and ASEAN region

The Greater Bay Area and ASEAN region printing industry has an opportunity to expand their customer base by redefining their corporate strategy, adopting digitalization, and entering new lucrative markets, such as packaging. Moreover, by staying abreast of changing market trends and collaborating closely with partners and customers, companies can capitalize on growth opportunities. Despite the digitalization of printing machines, there is still room for improvement in the digitalization level of post-printing processes. By prioritizing data-driven improvement processes, companies can leverage this opportunity to drive growth in the following 3 aspects:

1. Global Market Insight for Digitalization

Currently companies in GBA are serving to international customers and as print media is changing to digital, it is challenging for companies to find long term customers in a shrinking market. Companies have an opportunity to grow their customer base either locally or finding new segments of the market like packaging which are lucrative. The question of how to address new customers and prepare for new segments of markets need a redefined corporate strategy. As more high value products are being manufactured in GBA, new business opportunities are available. Formerly acting as an isolated industry, in the future printing companies will become a part of value chain which requires just in time delivery. Digitalization can help in entering new markets that are growing.

2. Digital Communication with Client

Sales forecasting can be a challenge for printing companies, especially with frequent changes in customer demands and order requests; however, partnering with customers and understanding their expectations can lead to better sales forecasts, improved customer service, and growth opportunities by making the process easier for smaller customers and attracting new ones.

3. Synchronization of Correctness of data

There is drastic difference in digitalization level on shopfloor in printing process and post-printing process. This is due to the printing machines are digitalized from the manufacturer, but post-printing machines are not well developed. Even if there are dashboards showing OEE using real times from shopfloor (by pressing start and stop in the system), calculations are usually not correct because data quality is very low. For some advanced companies, even if good quality data is available, fail to use it properly. Companies need to drive data-driven improvement processes and as a first step, aim to get correct data (Single Source of Truth).

4 Methodology

A	As aim of gaining an in-depth understanding of the current state of the printing sector for Hong Kong businesses, as well as identify any potential issues and further recommendations, HKPC and INC Invention Center carried out 15 pilot assessments. Through interviews with senior management and related departments, the maturity level of Print 4.0 applications for printing product production processes was evaluated accordingly. A portfolio of over 150 questions across eight dimensions was used to assess the visiting departments and procedures, taking multiple factors into account. The assessment structure and maturity level logic were based on the **Hong Kong Print 4.0 Maturity Model**, which is derived from the Acatech Industrie 4.0 Maturity Index formulated by German academic research organizations, along with the **Print 4.0 Navigator** created by INC Invention Center, Fraunhofer IPT, and HKPC.
Assessment & Roadmapping Approach	

B	To facilitate a structured and gradual transformation towards Print 4.0 in Hong Kong SMEs, the Hong Kong Print 4.0 Maturity Model was created and tailored to the local environment and needs. The model's stages and principles were derived from the Acatech Industrie 4.0 Maturity Index, which was developed by German academic research institutions.
Hong Kong Print 4.0 Maturity Model	

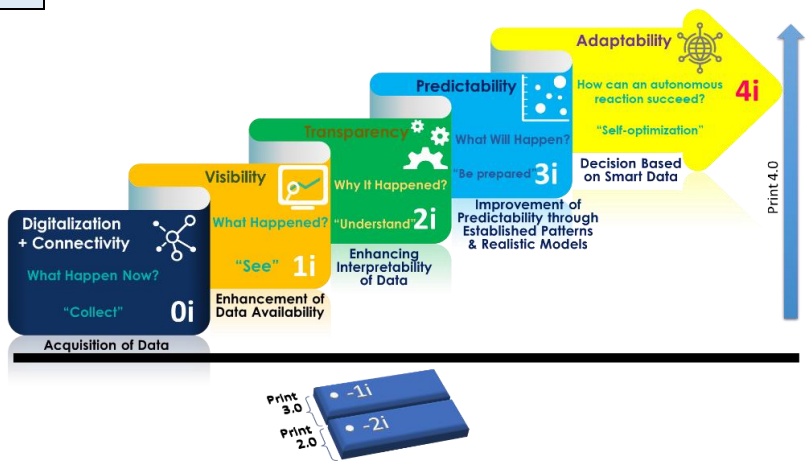


Figure 2: Maturity Levels

The transition towards Print 4.0 at each individual level provides businesses with additional value and a competitive edge. For ensuring capabilities growth sustainably, every change among levels should be introduced gradually and uniformly across all departments, instead of jumping suddenly. It is worth noting that solutions up to level 2i are currently available, cost-effective, and appropriate for industrial

application. However, solutions from levels 3 and 4 are still under development and require enhanced computing power, a high-performance IT infrastructure, and access to high-quality big data from multiple sources. Consequently, they are only viable and cost-effective for technologically advanced businesses.

Level -2 | Level -1 | Level 0 | Level 1 | Level 2 | Level 3 | Level 4

Print 2.0: Non-digital

Predominantly Print 2.0 process, characterized by labor-intensive activities and manual information transfer. Operations are primarily manual and paper-based, as well as ad hoc and chaotic, as opposed to methodical.

- Chaotic operation (Low attention level on efficiency and effectiveness)
- Manual operation processes/works
- Mainly paper-based work
- No digitization (No information technology/system adopted)

Level -2 | **Level -1** | Level 0 | Level 1 | Level 2 | Level 3 | Level 4

Print 3.0: Systemization and Computerization

Predominantly Print 3.0 procedures. Basic digitization, introduction of stand-alone IT solutions for automation of individual processes/tasks (e.g., e-mail & fax), and systematization of processes:

- Operations not yet optimized (Low efficiency and effectiveness)
- Standalone automation processes/works in place
- Basic digitization in place for processes/works
- Low level of digitization (Limited/disconnected information technology/system adopted)

Level -2 | Level -1 | **Level 0** | Level 1 | Level 2 | Level 3 | Level 4

Print 4.0: Connectivity - Foundation Condition

Organizational and infrastructural enablers for the deployment of Print 4.0. Interconnection of internal IT systems without media interruptions affecting the direction of information flow:

- Print 4.0 awareness and culture built
- LEAN processes & reasonable networked automation
- IT-infrastructure and data security
- Data acquisition by sensor and IoT in real time for processes/works
- Standalone advanced digital tools adopted & mastered

Level -2 | Level -1 | Level 0 | **Level 1** | Level 2 | Level 3 | Level 4

Print 4.0: Visibility - "What is happening?"

Real-time generation and availability of data and information for all actions. Effortless flow of information in all directions between internal and external information sources and IT systems, resulting in a "single source of truth" and transparency across all processes and activities:

- Vertical integration of advanced digital tools (e.g., MES, QMS, WMS)
- Delivery management, Track and Trace
- Well established "Single Source of Truth"
- Real time end-to-end printing process visualization
- Use of data for basic operation analysis (descriptive)

Level -2 | Level -1 | Level 0 | Level 1 | **Level 2** | Level 3 | Level 4

Print 4.0: Transparency - "Why does it happen?"

Through the study and compilation of all accessible information and data sources, knowledge and insights are created. Complete aggregation of internal and external real-time data to determine the cause-and-effect links between events and their root cause:

- Full digitalization & aggregation of real time data including EDI/APIs and IoT platform
- Collaboration within organization and agile management (e.g., planning/forecast ability & decision making, improvement)
- Smart Data analytics and machine learning adopted & mastered

Level -2 | Level -1 | Level 0 | Level 1 | Level 2 | **Level 3** | Level 4

Print 4.0: Predictability - "What will happen?"

For decentralized decision-making, predictive analytics and human-system / system-system collaboration are essential. Application of simulation models, which are based on actual historical data and are continuously refined, in order to anticipate the likely outcomes of certain events or decisions:

- Decentralized decision-making
- HMI/MMI, Industrial apps
- Mobile assistance systems
- Close-loop process optimization over the whole production process and predictive analytics

Level -2 | Level -1 | Level 0 | Level 1 | Level 2 | Level 3 | **Level 4**

Print 4.0: Adaptability - "How can an autonomous reaction succeed?"

Along the value chain, self-optimizing processes and autonomous control of processes. Addition of an automatic and autonomous evaluation function that can make a determination regarding which event or choice will result in the greatest possible outcome for the company and its customers:

- Autonomous automation
- Self-learning, self-organizing and self-optimization

C

Print 4.0 Navigator

The purpose of the Print 4.0 Navigator is to provide a structured approach to the assessments conducted in the Print 4.0 sector. It offers a framework that illustrates the relationship between a unique business model (Uniqueness), technology-driven applications for implementing the model (Application), and the underlying technologies which enable these applications (Enablers).

The fundamental concept of the navigator is centered around value creation, which should be the primary goal of every business action. Value can be created by boosting revenue and growth, as well as by reducing costs through improved production and efficiency. The creation of value for customers is vital for a company's success, as it determines its ability to attract and retain satisfied customers, ultimately leading to growth and revenue. To effectively align enablers, applications, and business models towards value creation, a company requires a consistent "Strategy and Organization" and a supportive "Mindset and Culture". These components are the foundation and internal environment of a thriving company.

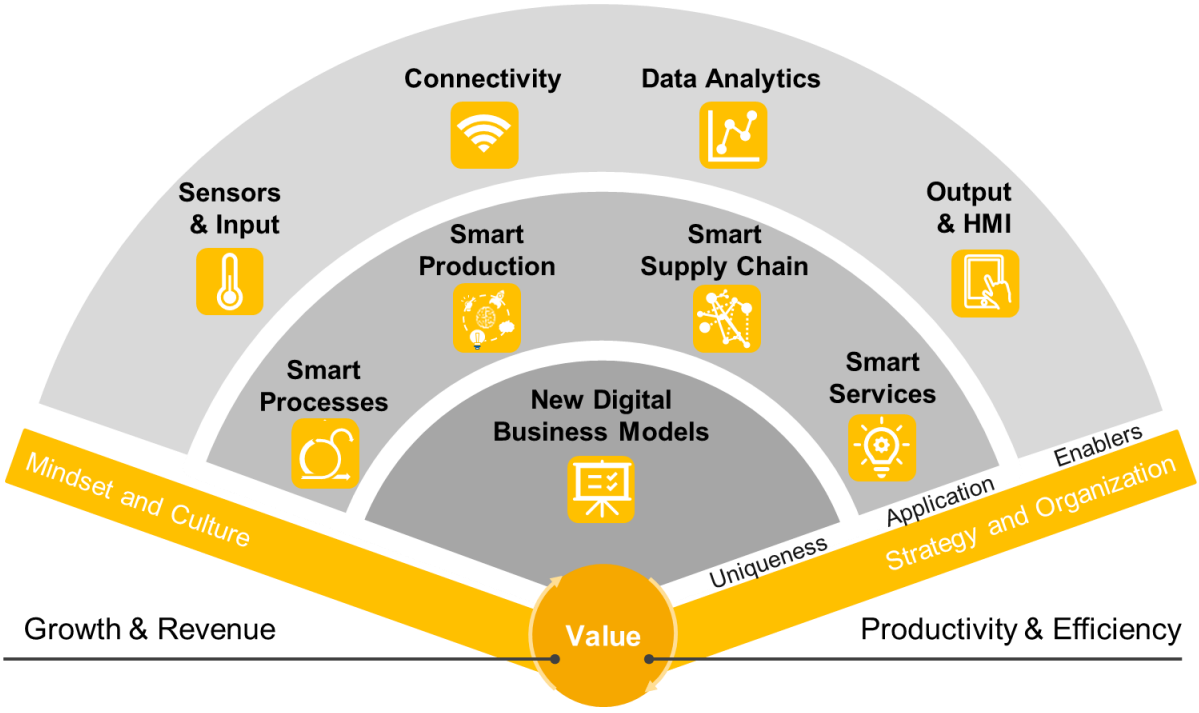


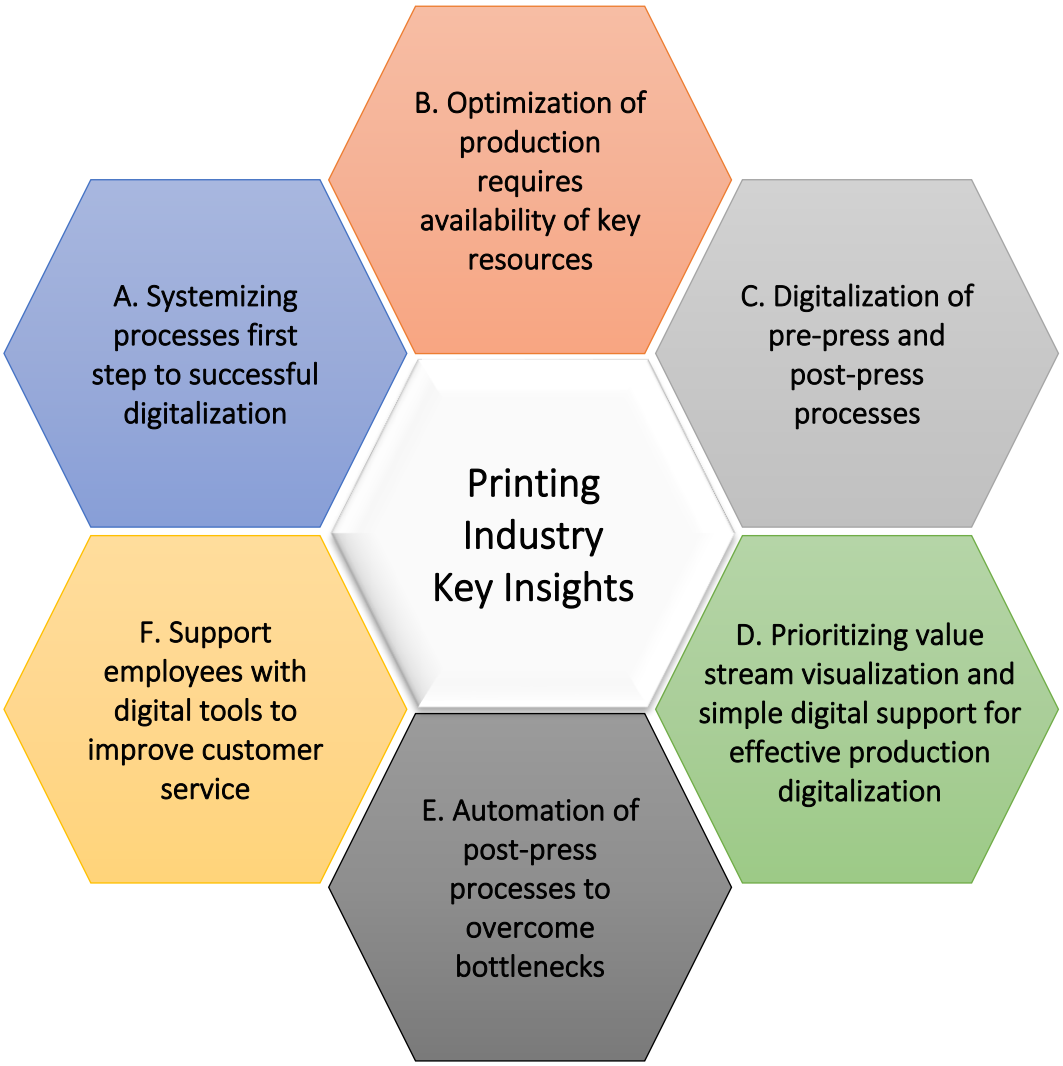
Figure 3: Print 4.0 Navigator

The **Print 4.0 Navigator** included critical elements which can be illustrated as:

New Digital Business Models	A company's business model is its basis and decides whether or not it will be successful and flourish. Industry 4.0 supports the creation of novel digital business models that are data-driven, data-driven in their development and improvement, and data-driven in their delivery to the client.
Smart Processes	The integration of entities and things along the whole supply chain enables a seamless data interchange across systems, goods, and stakeholders. In the printing sector, cloud-based printing platforms for customized B2B and B2C orders facilitate effective collaboration and workflow.
Smart Production	In addition to fostering greater internal openness, connectivity and smooth data interchange contribute to the efficacy of businesses. Internal departments and processes, such as warehousing, intra-logistics, and the shop floor, can be better controlled and monitored to offer internal and external stakeholders with timely and accurate information, such as current stock levels or production delays.
Smart Supply Chain	Printing systems may now perceive, process, learn on their own, evaluate data, and make decisions in order to solve problems and carry out operations thanks to technologies that fall under the Industry 4.0 umbrella. In order to get a holistic perspective of all printing processes and locate potential bottlenecks, the intelligent supply chain is connected to intelligent manufacturing systems as well as other networks.
Smart Services	The complete gathering of product and user data enables the provision of intelligent and value-added services based on the demands and behaviors of customers. This can apply, for instance, to the provision of QR codes and image recognition technologies for accessing other online material via augmented reality in the printing sector (AR).
Sensors & Input	The use of sensors and the capture of data from many IT systems enables the building of a comprehensive digital representation of the physical environment. This creates transparency throughout the whole supply chain's production processes and enables stakeholders to observe what is occurring. Sensors are getting increasingly compact, affordable, and multifunctional. They can measure more data in increasingly inaccessible regions and communicate with one another.

Connectivity	Industry 4.0 and Print 4.0 rely on the connectivity of all elements in the value network through horizontal integration of the supply chain, vertical integration of enterprise systems, and integration of the product life cycle from development to client consumption. Ad-hoc and automatic establishment of extensive networks enables access to data throughout the whole supply chain.
Data Analytics	Capabilities to analyze data add intelligence to the entire value chain and enable stakeholders to comprehend why something is occurring, predict future events such as production bottlenecks, and facilitate autonomous optimization such as rerouting and replanning. Modern information and communication technology (ICT) enables the storage of data in the cloud and provides computational and artificial intelligence (AI) application resources.
Output and Human Machine Interface	In addition to machine-controlled processes, the providing of information to the user is a significant theme in Print 4.0. Assistive technologies such as smartphones, tablets, and other wearables facilitate the user's data visualization and deliver user-specific and contextualized data. This can be used, for instance, to notify transport operators of anticipated delays in the manufacture of their customers' goods, or to assist warehouse operators in locating and identifying SKUs.

5 Key Insights for the Printing Industry



A. Systemizing processes first step to successful digitalization

Basic digitalization can be a powerful tool for identifying waste and bottlenecks in production processes, even in situations where advanced technology is not yet feasible. By implementing basic digitalization techniques, such as data collection and analysis, companies can gain valuable insights into their operations, identifying areas for improvement and optimizing their workflows.

However, before digitalization can be effective, it's essential to first systemize processes. This involves introducing a methodology such as LEAN, which is designed to optimize production processes by eliminating waste and increasing efficiency. By streamlining processes and eliminating unnecessary steps, printing companies can create a solid foundation for digitalization that will allow them to maximize the benefits of advanced technology when it becomes feasible.

Once processes have been systemized, printing companies can begin to implement more advanced digitalization techniques, such as automation and artificial intelligence. These technologies can help to further optimize production processes, increasing efficiency, reducing waste, and improving overall performance.

While advanced technology may not always be feasible, basic digitalization can still be a valuable tool for improving production processes. However, it's important to first systemize processes before implementing digitalization to ensure that the benefits of these technologies are maximized. By streamlining processes and eliminating waste, printing companies can create a strong foundation for digitalization that will allow them to optimize their operations and achieve greater success in the future.

B. Optimization of production requires availability of key resources

In manufacturing, especially printing industry, it's crucial to identify and control the availability of key machines, also known as bottlenecks, to ensure optimal production output. By focusing on the availability of bottlenecks, companies can prioritize their optimization efforts and reduce the risk of delays and downtime.

One way to optimize the availability of bottlenecks is to measure waiting times and set-up times for these machines. By analyzing these metrics, companies can identify opportunities to reduce downtime and increase throughput. For example, if waiting times for a particular machine are consistently high, companies may consider increasing the number of workers responsible for operating that machine or adjusting the production schedule to reduce demand during peak times.

Another way to optimize the availability of bottlenecks is to prepare required materials ahead of time by sending digital instructions to workers. By providing workers with clear and concise instructions, companies can reduce the time required for set-up and reduce the risk of errors or delays. This approach can also help to streamline production processes and reduce waste, as workers have a clear understanding of the materials required at each stage of the production process.

Overall, focusing on the availability of key machines and measuring waiting times and set-up times can help companies to optimize their production processes and increase efficiency. By preparing required materials ahead of time and providing workers with clear instructions, printing companies can reduce the risk of delays and errors, streamline production processes, and achieve greater success in the future.

C. Digitalization of pre-press and post-press processes

Digital processes have the potential to revolutionize the printing industry, from pre-press to printing and post-press. By digitizing these processes, companies can streamline their operations, improve efficiency, and reduce waste.

One area where digital processes can have a significant impact is in order handling. Paper-based order handling can be time-consuming and prone to errors, leading to decreased utilization and increased overhead. By digitizing the order handling process, companies can reduce the risk of errors and improve communication with customers, leading to faster turnaround times and increased customer satisfaction.

Digital processes can also improve utilization by reducing the amount of time required for set-up and changeover. By using digital workflows, companies can automate many of the tasks associated with pre-press and printing, reducing the time required for manual intervention. This can help to increase throughput and reduce downtime, improving overall efficiency.

In addition to improving utilization and reducing waste, digital processes can also provide valuable data and insights into the production process. By collecting and analyzing data on key performance metrics, such as production speed and defect rates, companies can identify areas for improvement and optimize their workflows to achieve better results.

Overall, digital processes offer significant potential for improvement in the printing industry, from pre-press to printing and post-press. By avoiding paper-based order handling and implementing digital workflows, companies can improve utilization, reduce overhead and time waste, and achieve greater success in the future.

Observations from the assessments	
Challenge	Solution
Observed that in pre-press processes like printing plate production requires effort in term of gathering customer requests and design requirement. Job orders are often paper-based and travel in folders along with the job order.	Digitalization of this paper-based process by providing job order information digitally will reduce the efforts of the employees and increase productivity.

D. Prioritizing value stream visualization and simple digital support for effective production digitalization

Once LEAN management is in place and structured process mapping has been done, printing companies can more easily identify which key measurements and process steps involve waste and should be digitalized. By focusing on these areas, printing companies can streamline their operations and optimize their workflows, leading to increased efficiency and reduced waste.

In most cases, it's not recommended to focus on machine details or process details that require expensive software or retrofitting. Instead, printing companies should focus on basic value stream visualization with simple digital support. For example, digitally tracking the times of operation and waiting of a machine, tracking the times of processing and waiting of an order, and tracking personnel usage times can all provide valuable insights into the production process and help to identify areas for improvement.

By using these basic digital tools, printing companies can gain a better understanding of their operations and identify opportunities to reduce waste and increase efficiency. For example, by tracking the time required for each step of the production process, companies can identify bottlenecks and streamline their workflows to reduce waiting times and increase throughput.

E. Automation of post-press processes to overcome bottlenecks

In many manufacturing processes, post-press operations have been identified as bottlenecks, and this is particularly true in the printing industry. These processes are often still handled manually, leading to increased waiting times and decreased throughput. As a result, it's worth exploring the potential benefits of automation for post-press operations.

One area where automation could have a significant impact is in feeding for binding. This is a process that is typically done manually, and it can be time-consuming and prone to errors. By automating this process, companies can reduce the time required for binding and increase throughput, leading to faster turnaround times and increased customer satisfaction.

In addition to reducing waiting times and increasing throughput, automation can also help to reduce errors and improve quality. By using automated systems for feeding and other post-press operations, companies can reduce the risk of mistakes and improve consistency, leading to higher-quality finished products.

Of course, it's important to consider the ROI of automation before investing in new equipment or systems. However, in many cases, the time savings and increased throughput that can be achieved through automation can more than offset the cost of the investment. By carefully analyzing the costs and benefits of automation, companies can make informed decisions and achieve greater success in the future.

Exploring the potential benefits of automation for post-press operations is a worthwhile endeavor for companies in the printing industry. By automating processes such as feeding for binding, companies can reduce bottlenecks, increase throughput, improve quality, and achieve greater success in the future.

Observations from the assessments	
Challenge	Solution
Post processes like folding and packaging in most SMEs are done manually and therefore it is not really possible to find out the actual production times.	Automation of these processes will reduce the manual processes and remove bottlenecks.

F. Support employees with digital tools to improve customer service

For many small and medium-sized enterprises (SMEs), flexibility in serving customer needs is a key distinguishing factor that sets them apart from larger competitors. To maintain this flexibility, it's important to strike a balance between digitalizing processes and supporting employees in their work. While digitalization can help to streamline workflows and improve efficiency, it's important to do so in a way that doesn't sacrifice flexibility or the ability to respond quickly to customer needs.

One way to balance digitalization with flexibility is to reduce the need for double entry, information copying, and paper forms. By using digital tools to automate routine tasks and reduce manual data entry, employees can focus more on customer interactions and other value-adding activities. This can help to improve customer satisfaction and increase the overall efficiency of the business.

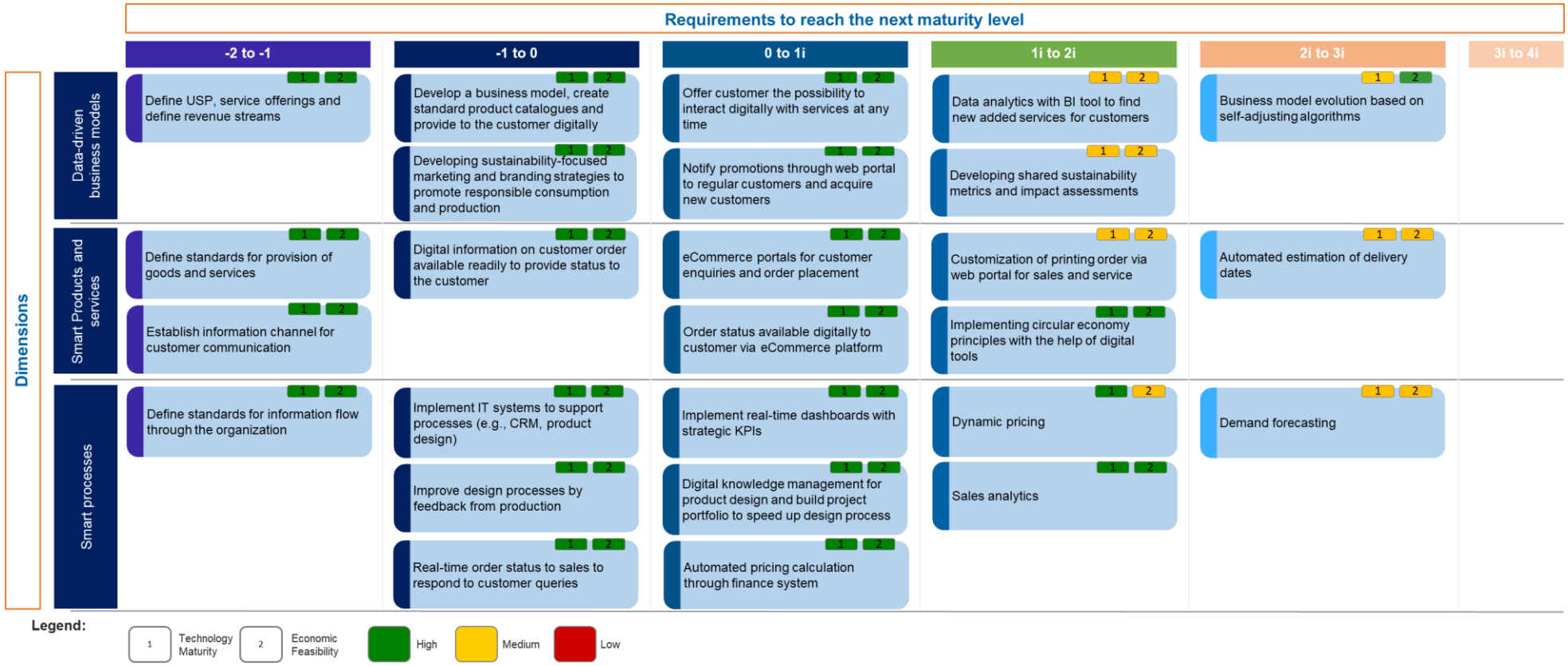
However, it's important to avoid fully digitalizing process flow in a way that limits flexibility. This can be achieved by implementing digital tools that support rather than replace human decision-making. For example, rather than implementing a fully automated ordering system, companies could use digital tools to provide customers with a range of options and recommendations while still allowing them to customize their orders as needed.

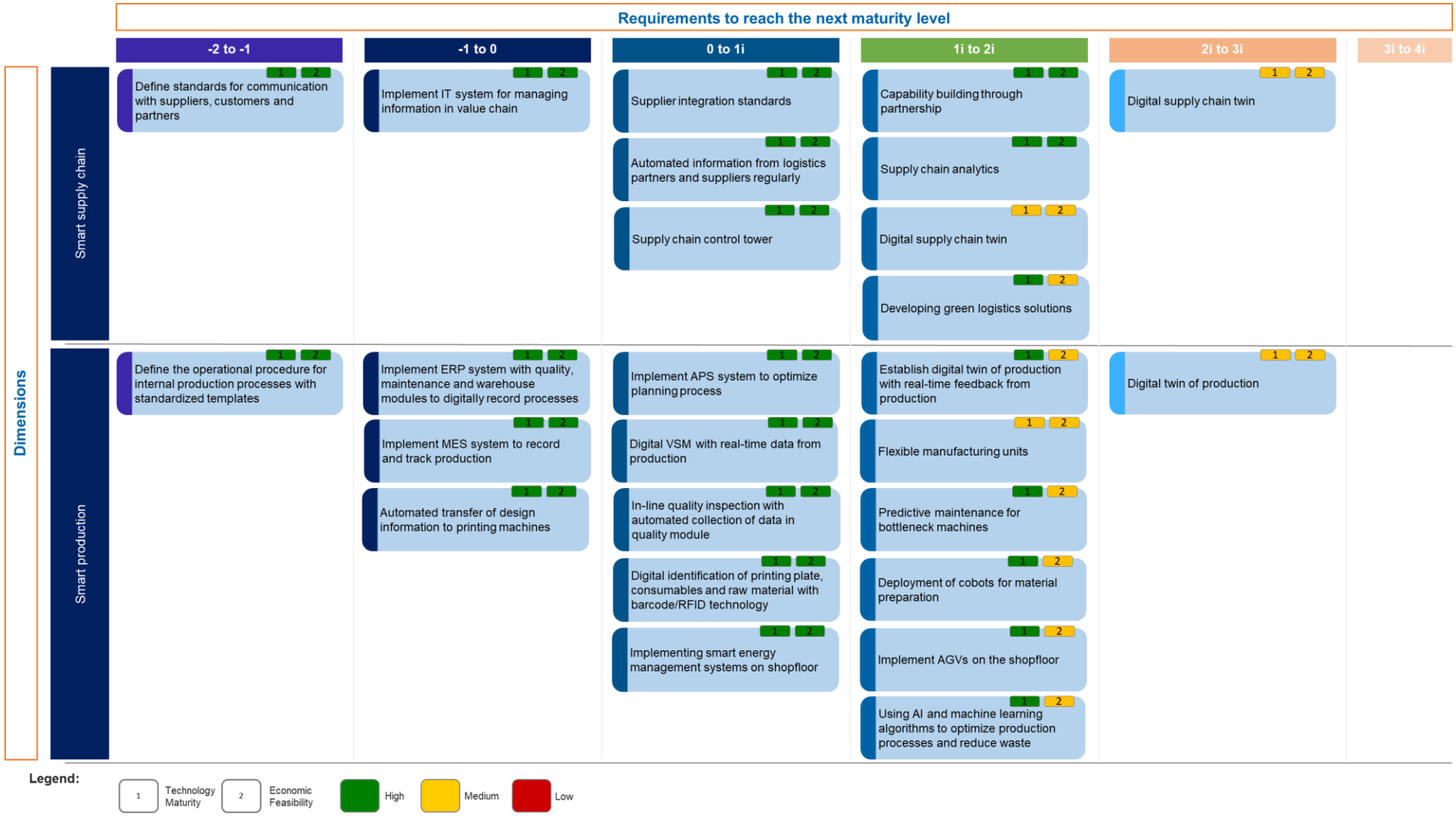
Overall, for SMEs, maintaining flexibility in serving customer needs is essential for success. By balancing digitalization with employee support and avoiding overly rigid process flow, companies can achieve greater efficiency and customer satisfaction while still maintaining the flexibility that sets them apart from larger competitors.

Observations from the assessments	
Challenge	Solution
The whole sales process, specially getting customer requests is still very manual done via email and requires a lot of back and forth communication.	Digitalizing this process, by e.g., creating a web-based platform for customer orders and use of ERP system will provide better information on product status, etc. and could support new customer acquisition.

6 Roadmap for the Printing Industry

Roadmap including use cases for step-by-step transformation towards Print 4.0




Requirements to reach the next maturity level
-2 to -1
-1 to 0
0 to 1i
1i to 2i
2i to 3i
3i to 4i
Dimensions
Smart supply chain
Define standards for communication with suppliers, customers and partners
Implement IT system for managing information in value chain
Supplier integration standards
Automated information from logistics partners and suppliers regularly
Supply chain control tower
Capability building through partnership
Supply chain analytics
Digital supply chain twin
Developing green logistics solutions
Digital supply chain twin
Smart production
Define the operational procedure for internal production processes with standardized templates
Implement ERP system with quality, maintenance and warehouse modules to digitally record processes
Implement MES system to record and track production
Automated transfer of design information to printing machines
Implement APS system to optimize planning process
Digital VSM with real-time data from production
In-line quality inspection with automated collection of data in quality module
Digital identification of printing plate, consumables and raw material with barcode/RFID technology
Implementing smart energy management systems on shopfloor
Establish digital twin of production with real-time feedback from production
Flexible manufacturing units
Predictive maintenance for bottleneck machines
Deployment of cobots for material preparation
Implement AGVs on the shopfloor
Using AI and machine learning algorithms to optimize production processes and reduce waste
Digital twin of production
Legend:
1 Technology Maturity
2 Economic Feasibility
High
Medium
Low

Funded by SME Development Fund
工業貿易署 Trade and Industry Department
Organiser
香港印刷業商會 THE HONG KONG PRINTERS ASSOCIATION
Implementation Agent
hkpc 生產力局
Strategic Partner
Fraunhofer IPT

7 Print 4.0 Use Cases and Applications

More information on the advantages of each pilot project on the roadmap, along with a description of the particular use case or application. The description of dimension is as follow:

1. **Data Driven Business Models** - Defining value proposition and revenue model using data
2. **Smart Products and Services** - Additional value for direct or end-customer
3. **Smart Processes** - Internal information flow for non-physical processes
4. **Smart Supply Chain** - Information flow with partners, suppliers and customers
5. **Smart Production** - internal material & information flow for processes with physical counterpart
6. **Smart Technologies** - technology enablers / Infrastructure
7. **Strategy & Organization** - co-ordination of resources
8. **Culture & Mindset -** co-ordination of mindset / approaches

Level -2 to -1: The first step is the conversion of activities that are primarily Print 3.0 processes from non-digital, highly manual, and paper-based (more ad hoc and chaotic than methodical) operations.

-2 to -1	**Define USP, service offerings and define revenue streams**	1 2
Data-driven business models	USP is widely known - internally and externally, what kind of capabilities do our people, machines have that are valueable to customers, what brings us profit, setting pricing model etc.	
-2 to -1	**Define standards for provision of goods and services**	1 2
Smart Products and Services	Defining how services are provided to the customer, standard procedure for how customer requests will be processed. This can ensure that customers receive a consistent and high-quality experience. This can help to improve customer satisfaction, build loyalty, and ultimately drive business growth.	
-2 to -1	**Establish an information channel for customer communication**	1 2
Smart Products and Services	Define standards for how customer communications will occur and how they will be further processed, creating standard templates for offers, defining lead times for answering customer requests and processing quotations.	
-2 to -1	**Define standards for information flow through the organization**	1 2
Smart processes	Defining which departments are responsible for each internal process, what information needs to be made available to relevant departments and setting standards for information availability and channels of communication.	

-2 to -1	**Define standards for communication with suppliers, customers and partners**	1 2
Smart supply chain	Defining standards for communication in supply network, SOP for interaction with partners, suppliers and customers, creating templates for supplier orders, reduce miscommunication and delay in information transfer in the supply chain.	
-2 to -1	**Define the operational procedure for internal production processes with standardized templates**	1 2
Smart Production	Define SOP for shopfloor activites, roles and responsibilites are clearly known to all, how commercial information and information about adjacent processes are communicated - e.g., urgencies, high value orders, etc., and use standard templates for information transfer.	
-2 to -1	**Use of computer applications for managing processes**	1 2
Smart Technologies	No more physical documentation and moving from paper-based processes to use of computer-based applications to record and store information, information is not stored as papers in folders, but in digital format so that it can be easily retrieved.	
-2 to -1	**Define IT governance framework**	1 2
Strategy & organisation	Set guidelines and standards for IT framework, strategic alignment of IT framework with the corporate strategy. Company can ensure that its IT resources are aligned with its business goals and objectives. This can help to improve the overall efficiency and effectiveness of the organization, resulting in increased productivity, reduced costs, and improved customer satisfaction.	
-2 to -1	**Create mindset for compliance to the standard procedures**	1 2
Culture & mindset	Create awareness about why standardization is important, promote culture of adherence to standard operating procedures and need to follow defined processes. Especially for those company want to improve their efficiency, reduce waste, and enhance the quality of their products or services. By standardizing processes, organizations can improve productivity, reduce costs, enhance safety, and promote consistency. Moreover, standardization can help to create a culture of continuous improvement, where processes are regularly reviewed and refined to ensure that they remain effective and efficient over time	

Level -1 to 0: Basic systemization of operations is carried out, along with rudimentary digitization and the installation of standalone IT systems for automating specific jobs or processes. By implementing the following steps, the next stage with links to internal IT systems without media breaks can be reached.

-1 to 0	**Develop a business model, create standard product catalogues and provide to the customer digitally**	1 2
Data-driven business model	Make customers aware of what standard products are available and also what customization is possible, plan marketing roadmap to make it visible to target customers. By digitizing this, it can help increasing its sales, improve customer satisfaction, and enhance its brand reputation.	

-1 to 0	**Developing sustainability-focused marketing and branding strategies to promote responsible consumption and production**	1 2
Data-driven business model	By developing sustainability-focused marketing and branding strategies, businesses can build a reputation as a responsible and sustainable brand, attract environmentally conscious customers, and contribute to the achievement of sustainable development goals.	
-1 to 0	**Digital information on customer order available readily to provide status to the customer**	1 2
Smart Products and Services	All needed information about customer order is available readily to the sales or customer management team to provide the customer quick and assured information about the current status of their ongoing order	
-1 to 0	**Implement IT systems to support processes (e.g., CRM, product design)**	1 2
Smart processes	Providing digital tools to employees to support them in their functions and better manage their tasks and record information. Employees and company can benefit from improving efficiency, increasing productivity, enhancing the quality of products or services, improving collaboration and communication, and attracting and retaining top talent	
-1 to 0	**Improve design processes by feedback from production**	1 2
Smart processes	Generate a feedback loop to fasten the product design functions by providing the sampling and design department with the information on changes of the parameters on shopfloor so that it can be used for repeating orders and reduce time required for design approval process	
-1 to 0	**Real-time order status to sales to respond to customer queries**	1 2
Smart processes	For new enquiries, overview to the sales about the internal capacities, material availability so that they can provide guaranteed information to the customer about the delivery deadline without having to call/send paper-based request to manufacturing thus reducing response time to customer	
-1 to 0	**Implement IT system for managing information in value chain**	1 2
Smart Supply Chain	Assess the need of IT tools or modules of ERP system where supply chain data can be managed and suppliers can be integrated. This can create a horizontal integration and improve supply chain visibility, reduce costs and enhance supplier collaboration.	
-1 to 0	**Implement ERP system with quality, maintenance and warehouse modules to digitally record processes**	1 2
Smart Production	Implement ERP system to record and manage core business processes, either separate systems or add-on modules for managing quality, maintenance and warehouse modules to get an overview of processes and manage it digitally	

-1 to 0	**Implement MES system to record and track production**	1	2
Smart Production	MES system that integrates with ERP, record all production relevant data and capture production times, production history, ongoing manufacturing orders and thus get an overview of capacities and production efficiency		
-1 to 0	**Automated transfer of design information to printing machines**	1	2
Smart Production	Customer approved design can be automatically transferred to the printing machine via suitable interfaces to avoid any delays in machine set-up times. This can help to ensure the final products meets their requirements and expectation.		
-1 to 0	**Use of digital collaboration tool for internal communication**	1	2
Smart Technologies	Eliminate communication via emails and phone calls and enable efficient communication between departments and all relevant people so that discussions occur faster and decisions are not delayed		
-1 to 0	**Set up basic IT Infrastructure with WiFi/Internet coverage**	1	2
Smart Technologies	A good IT infrastructure necessary to enable implementation of softwares and machine connectivity, build an infrastructure with future projects according to the roadmap in mind. This create the framework of vertical and horizontal integration to ensure the connectivity of each system.		
-1 to 0	**Machine interfaces to interact with machines**	1	2
Smart Technologies	Machines have standard interfaces that helps the operator to interact with the machine on the shopfloor and enter or change machine settings. This enhance the operator's ability to control the machine, improving training and knowledge transfer and ultimately improving safety during operation of machine.		
-1 to 0	**Establish Lean approach starting with 5S methodology**	1	2
Strategy & Organization	Start implementation of lean values to reduce waste and organize the shopfloor with defined areas for optimized flow of material reducing transportation times. The defined area can also isolate the flow of material without interuption which result improving efficiency		
-1 to 0	**Create awareness for usage of IT systems and importance of data**	1	2
Culture & Mindset	Inform the employees the importance of data and how it can help to drive improvement, IT systems are tools for supporting employees in their tasks should be known to all to avoid any workarounds, accepting technology for benefit of individual and company		

Level 0 to 1i: The following level provides seamless, real-time information flow between internal and external information sources and IT systems in all directions. One of the key responsibilities at this level is to establish a "single source of truth" and more transparency across all processes and activities.

0 to 1i	**Offer customer the possibility to interact digitally with services at any time**	1 2
Data-driven business model	Providing an online platform where customers can see the services offered, less interaction via emails. As email also involve manual checking in which human error cannot be avoided, online platform can offer 24 hours seamless log to customer in regardless of location.	
0 to 1i	**Notify promotions through web portal to regular customers and acquire new customers**	1 2
Data-driven business model	Information to the customers about new deals and promoting services through website, offers provided digitally to the customers to increase sales. This faciliate the engagment between customer and they can know more precisely about what you can offer	
0 to 1i	**eCommerce portals for customer enquiries and order placement**	1 2
Smart Products and Services	Less waiting time for customers, one single platform for sales team to get customer enquiries and orders, visibility on pending customer rfqs and provide price proposals. By anyalzing their order and activities, sales forecasting can also be avheived.	
0 to 1i	**Order status available digitally to customer via eCommerce platform**	1 2
Smart Products and Services	Customers can see the status of the order via webportal, added service to the customer to increase customer satisfaction. Reducing the back and forth email communication for the order status	
0 to 1i	**Implement real-time dashboards with strategic KPIs**	1 2
Smart processes	Derieve KPIs based on the company strategy and use the data from IT systems to create graphs, make dashboards where the KPIs are tracked and also visible to the management so that they can know the performance of shopflorr equipment and figure out the bottle neck and pain point	
0 to 1i	**Digital knowledge management for product design and build project portfolio to speed up design process**	1 2
Smart processes	Record knowledge of projects digitally and create a knowledge bank of all the projects so that this information can be referred to in the future and optimize design process, preserving intelligence and experience of the employees for company benefit	

0 to 1i	**Automated pricing calculation through finance system**	1	2
Smart processes	Set price models for products and services which will help in automatic price calculation thus reducing the efforts of the employees and fast processing of rfqs. This rapid output enhance the comptivieness in the market and response the customer inquiries more quickly and efficiently		
0 to 1i	**Supplier integration standards**	1	2
Smart supply chain	Set standards for connecting supply chain partners' system with internal IoT platform for automated information. Improving its supply chain visibility, enhance collaboration with partners, and improve operational efficiency		
0 to 1i	**Automated information from logistics partners and suppliers regularly**	1	2
Smart supply chain	Enable automated information flow through integration through APIs so avoid phone calls with suppliers and logistics providers and seamless service without delays. Through system intergration, order can be made automaticaly to aovid shortage of material in the production floor		
0 to 1i	**Supply chain control tower**	1	2
Smart supply chain	Overall visibility on supply chain and central information on where raw materials and finished customer goods are in the transportation channels. Company can better plan and coordinate its supply chain acitivities to reduce lead time, minmize inventory levels.		
0 to 1i	**Implement APS system to optimize planning process**	1	2
Smart Production	APS system will help to manage the complex planning process better by taking all planning rules and restrictions into account and ease the task of planning and optimize the machine utilization and use capacitites to the fullest		
0 to 1i	**Digital VSM with real-time data from production**	1	2
Smart Production	Further implement lean tool of VSM by mapping material and information flow by capturing real-time data from shopfloor with tracking and trace technologies, compare actual cycle times with calculated values and find opportunities for improvement		
0 to 1i	**In-line quality inspection with automated collection of data in quality module**	1	2
Smart Production	Use digital technologies like in-line camera system to test the quality of the print and collection of the digital records in the quality management system or the quality module to prevent quality defects from happening and modifying the process to meet quality standards		

0 to 1i	**Digital identification of printing plates, consummables and raw material with barcode/RFID technology**	1 2
Smart Production	Digitally record all materials needed for production using barcode or RFID technology for quick identification. All the necessaities can be tracked and traced which increase the visibility of inventory.	
0 to 1i	**Implementing smart energy management systems on shopfloor**	1 2
Smart Production	IoT sensors can be placed throughout the shopfloor to monitor energy usage in real-time. These sensors can track electricity consumption, temperature, humidity, and other factors that affect energy usage.	
0 to 1i	**Retrofitting of legacy machines and automation of manual manufacturing processes**	1 2
Smart technologies	Adding sensors to the machines to capture process data, connecting machines to the MES system to record the process without manual input, further automating any manual processes - specially post-printing processes like labelling and packaging	
0 to 1i	**Set standards for connecting edge devices with IoT platform for real-time data collection**	1 2
Smart technologies	Specify machine connectivity and IoT standards with universally acceptable specifications and standards to collect data in real-time. This can ease the vertical system integration and align the latency data follow	
0 to 1i	**Set up IoT center to centrally collect data from machines**	1 2
Smart technologies	Implement cloud solution for central collection of stored data with ability to connect to other business applications. Allowing cloud computing and implmentation of AI algorthirm.	
0 to 1i	**Digital dashboards and scanners to record and display orders at work stations**	1 2
Smart technologies	Use of scanners for automatic recording production start and stop and display of customer orders digitally through work instruction screens eliminating need for paper-based work orders	
0 to 1i	**Using IoT sensors to monitor resource usage, such as water or electricity**	1 2
Smart technologies	By using IoT sensors to monitor resource usage, organizations can improve efficiency and reduce costs. For example, they can identify leaks or inefficiencies in water or electricity usage and take steps to address them.	

0 to 1i	**Build digital strategy based on company goals**	1 2
Strategy & Organization	Define a digital strategy which aligns with company goals and helps to define a roadmap for digitalization projects and drive KPIs. This involves identifying the key business drivers and determining how digital technologies can help to achieve these objectives. For example, if the company's goal is to increase sales, the digital strategy may focus on implementing e-commerce platforms or improving the customer experience through digital channels.	
0 to 1i	**Formulate cross-functional teams for driving digital strategy**	1 2
Strategy & Organization	Usually digital strategy implementation requires cross-departmental people with varied knowledge and capabilites to work together on a common goal with result in improving employee engagement and efficiency towards the goal.	
0 to 1i	**Integrating sustainability into a digital strategy**	1 2
Strategy & Organization	Sustainability and digital strategy are closely linked, as digital technologies can be used to drive sustainability initiatives and promote sustainable practices.E.g., data-driven sustainability for measuring sustainability performance and identify ideas for improvement	
0 to 1i	**Promote cross-departmental knowledge transfer**	1 2
Culture & Mindset	Create a culture where employees from different functions and departments come together and share knowledge and information and work strategically towards improvement of organization	
0 to 1i	**Promote acceptance and usage of data and IT systems**	1 2
Culture & Mindset	Make employees realise the value of data collection and usage and how it can support in continuous improvement. Encouraging employee to take a proactive approach to data management, ensuring the data is accurate, complete, and consistent.	

Level 1i to 2i: To uncover cause-and-effect links between events and their underlying causes, a comprehensive aggregation of internal and external real-time data is sought after with the transition from level 1i to level 2i.

1i to 2i	**Data analytics with BI tool to find new added services for customers**	1 2
Data-driven business model	Explore new markets, increase customer base, find innovative services for customers and know what capabilities will be required to serve future customers with the help of business intelligence tool by analyzing market data and changing customer requests	

1i to 2i	**Developing shared sustainability metrics and impact assessments**	1 2
Data-driven business model	By developing shared sustainability metrics and impact assessments, stakeholders within the digital ecosystem can promote sustainability governance and work towards achieving sustainable development goals.	
1i to 2i	**Customization of printing order via web portal for sales and service**	1 2
Smart Products and Services	Provide customers the possibility of customizing their orders and see added services through web platforms so that increase the accuracy of the order and provide a better customer service.	
1i to 2i	**Implementing circular economy principles with the help of digital tools**	1 2
Smart Products and Services	Prioritize the reduction of waste and the preservation of resources. Digital tools support in transition towards circularity by streamlining processes, reducing material waste, and increasing efficiency. E.g. digital tools can help track the usage of printing materials and ensure they are recycled or repurposed as much as possible.	
1i to 2i	**Dynamic pricing**	1 2
Smart Processes	Dynamic price calculation using data analytics that takes into account the seasonality, competition and market demand along with cheapest production method. This can reduce the expense and maximize the profits along each project.	
1i to 2i	**Sales analytics**	1 2
Smart Processes	Use of historical data to generate insights on sales turnovers, new marketing campaigns, analyse new product introduction and new customer acquired, etc This can improve sales forcasting and enhance business expansion	
1i to 2i	**Capability building through partnership**	1 2
Smart supply chain	Developing partners for missing capabilities, use of analytics to determine future demands by customers and finding partners to enable new services. This improve its competitiveness, enhance its customer experience, and expand its service offerings.	
1i to 2i	**Supply chain analytics**	1 2
Smart supply chain	Using real-time information from supply chain to measure supplier performance, data analysis to optimize flow of goods with help of data analytics. Supplier can also be brenchmarked to assist with selection of supplier to improve quality.	

1i to 2i	**Digital supply chain twin**	1 2
Smart supply chain	Digital representation of supply chain with real-time input of data to create graphs and visualization to understand the trends and better plan manufacturing. Company can improve its supply chain visibility, enhance decision-making capabilities, and optimize manufacturing processes.	
1i to 2i	**Developing green logistics solutions**	1 2
Smart supply chain	This can help ensure that their products are transported in an environmentally friendly way, reducing the environmental impact of the printing industry as a whole. Company can build up their reputation and attract more customers.	
1i to 2i	**Establish digital twin of production with real-time feedback from production**	1 2
Smart Production	Simulation-based digital representation of production shopfloor with real-time feedback of data to visualize and control production remotely. Production process can also be simulated to predict the best flow for production.	
1i to 2i	**Flexible manufacturing units**	1 2
Smart Production	Flexible printing and post-printing machines or production cells that for quick changeover of products or customer orders. This increase the flexiability to adapt rapid market change.	
1i to 2i	**Predictive maintenance for bottleneck machines**	1 2
Smart Production	Monitoring the conditions of machines by using the real-time sensor data to find trends that might lead to breakdown of machines and hinder production. Production balance can be optimzied to reduce downtime of breaking machine.	
1i to 2i	**Deployment of cobots for material preparation**	1 2
Smart Production	Use of cobots that work together with the humans for machine tending applications, support logistical processes of warehouse picking. For example, handling the paper lot from one machine to another which can speed up the changeover of material.	
1i to 2i	**Implement AGVs on the shopfloor**	1 2
Smart Production	AGVs can support automated and continuous supply of material to the workstations and movement of semi-finished goods on the shopfloor. AVGs can be commended and maximize the efficiency of material flow.	

1i to 2i	**Using AI and machine learning algorithms to optimize production processes and reduce waste**	1 2
Smart Production	By identifying inefficiencies, automating tasks, and reducing waste, AI and machine learning algorithms can help businesses to reduce their environmental footprint and increase profitability.	
1i to 2i	**Develop single source of truth**	1 2
Smart Technologies	Create a single source of truth by connecting all IT systems and platforms like eCommerce, ERP, MES and IoT platform and aggregating data centrally to remove data silos and bring consistency and quality to the data	
1i to 2i	**Set up BI tool**	1 2
Smart Technologies	BI tool is necessary to analyse the large amount of gathered data from processes and production to create reports, dashboards and visualization that support the employees in decision-making and optimize performance	
1i to 2i	**Implement data governance framework**	1 2
Strategy & Organization	With the huge amounts of data being captured, data governance framework is necessary to define policies and standards in the organization to understand data quality and capture value from it.	
1i to 2i	**Set up continuous improvement teams**	1 2
Strategy & Organization	Set-up a a team to create a culture of continuous improvement and actively drive and handle projects. The cost can be reduced and enhance their innovation capabilites.	
1i to 2i	**Qualify employees to handle and analyse data**	1 2
Strategy & Organization	Train employees to use data for analysing it, understanding the correlations and derieving actionable insights, hiring data scientist who can work well with data. This can improve the correctiveness of use of data which can maximize the output of digitaization.	
1i to 2i	**Develop agile working culture**	1 2
Culture & Mindset	Develop a mindset where employees work in a agile style, ie, collaborating and learning, strongly promoted by leadership, teams work in a self-organizing way. By adopting an agile approach, the organization can respond quickly to changing market conditions and customer needs. This can help to reduce time to market and improve overall competitiveness.	

1i to 2i	**Enable data-driven decision making**	1 2
Culture & Mindset	Create a culture where data is considered as an asset and trust on results of data analysis and is used by everyone in the organization and not just data owners and data scientists for making decisions and optimizing performance	

Level 2i to 3i: Predictive analytics, human-system and system-system collaboration, and decentralized decision-making are required for the transformation to level 3i.

2i to 3i	**Business model evolution based on self-adjusting algorithms**	1 2
Data-driven business model	Machine learning algorithm for adjusting the business model according to market changes and the environment of business. By analyzing data on market trends, customer preferences, and environmental factors, the organization can make informed decisions about its business model. This can help to improve overall efficiency and reduce costs.	
2i to 3i	**Automated estimation of delivery dates**	1 2
Smart Products and Services	According to print complexity and providing customer information on effects of design changes, e.g., in case customer changes certain design element by 11th of next month then they can meet the deadline since raw material will be delivered in time of production start, but if design is changed on a later date, then delay by 1 week as schedule for next days is busy	
2i to 3i	**Demand forecasting**	1 2
Smart Processes	Use of AI methods to accurately forecast demand using historical customer data and market analysis. By accurately predicting demand, the organization can optimize its inventory levels, reducing the risk of overstocking or stockouts. This can help to reduce inventory holding costs and improve overall efficiency.	
2i to 3i	**Digital supply chain twin**	1 2
Smart Supply Chain	Further develop supply chain twin by using simulation and AI algorithms to test possible scenarios and predict how decisions will affect and prepare for any disruptions	
2i to 3i	**Digital twin of production**	1 2
Smart Production	Simulate scenarios with digital twin to identify risks as well as optimize costs and efficiency, test real-world scenarios to steer future decisions. To simulate various scenarios, the organization can identify potential risks and their impact on operations. This can help to reduce the likelihood and severity of disruptions and ensure continuity of operations.	

Level 3i to 4i: Based on the assessments and research, it is evident that currently the dimension of adaptability is beyond scope for the printing industry and no best practices are seen.

8 Technology Landscape

There has been a significant rise in the application of various technologies with the aim of enhancing the robustness and productivity of supply chains. According to the Print 4.0 Navigator, technologies can be categorized in accordance with the enablers layer, which contributes to the successful execution of a particular use case from the roadmap.

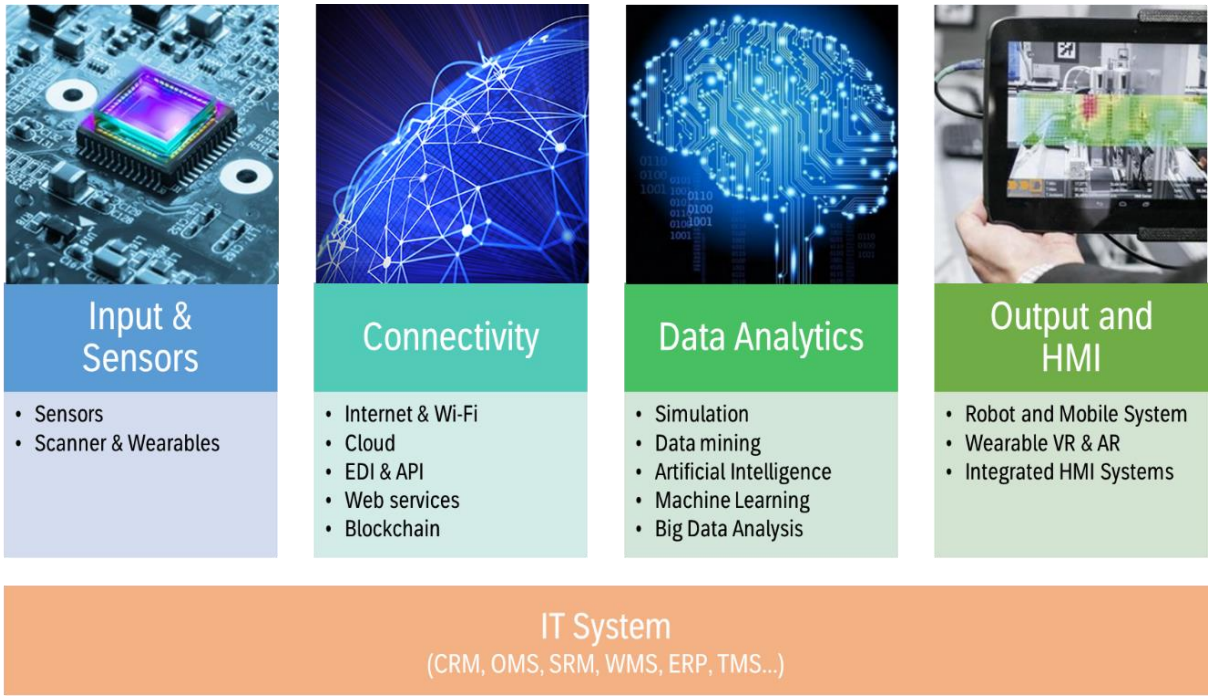


Figure 1: Technology Landscape

The graphic above depicts the technologies that can be employed throughout the Printing processes and are classified based on their applicable application areas. The following technologies are changing the way printing processes function today:

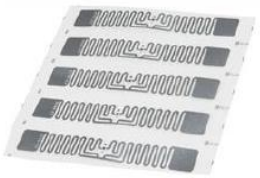
Input and Sensors

Sensors

While data-driven decisions are a key component of Print 4.0, it is crucial to acquire sufficient data of high quality with sensors. Internet of Things (IoT) facilitates the tracking of commodities and assets and the transfer of this data via the internet. Secure tracking of high-value items, worker support, mobile and wearable devices, inventory tracking with barcodes and scanners, and automated guided vehicles are just a few of the various ways in which Internet of Things devices are used in the printing industry. Specifically, Color Sensors can be used to ensure the colors in printed materials are accurate. They can detect color variations and make adjustments to the print process to secure the colors consistency. In addition, pressure applied during the printing process can be measured by Pressure Sensors which able to maintain the pressure is at correct level so as to avoid damage caused to the printing equipment or materials.

Scanners and wearables

Marker technologies, for instance, barcodes, QR codes, RFID tags and read, as well as high-resolution cameras, play a crucial role in identifying materials throughout the printing processes. By leveraging these scanning devices, the data gathered can be seamlessly transmitted to the relevant IT system, and hence eliminating the need for manual updates on the completion of each process step.



RPA

The utilization of Robotic Process Automation (RPA) can enhance the efficiency and effectiveness of printing production through the automation of quality control tasks, for instance, error checking in printed materials, verification of color accuracy, and ensuring proper material alignment. This accessible technology can significantly reduce time and effort by automating mundane but necessary activities. The RPA employs software robots to automate the process of copying and pasting information from one software system to another. In addition, the integration of chatbots and mobile apps can further complement RPA by improving the customer service experience through automated updates on the order's progress and any potential delays.

Connectivity

Internet and Wi-Fi

5G enables rapid data transmission with reduced latency and improved dependability. IoT devices may now have more stable network connections thanks to 5G, making it a crucial component of Print 4.0. Value chain visibility is achieved through the transfer of data created in real time utilizing 5G technology. The internet and WiFi enable remote printing and wireless printing significantly. It allows users to send print jobs to printer from anywhere without the need to be physically present in front of the printer. Alternatively, wireless printing provides feasibility to users to print documents from their mobile devices or laptops without the need for cables or other physical connections while the printing space is limited.

Cloud Technology

In order to collaborate between departments and anticipate bottlenecks, printing processes require a single authoritative source of information. With cloud computing, all participants in the value chain can be linked, and data stored remotely can be made accessible to various parties. Together, Internet of Things devices enables tracking of printing activities as well as the pre-processes and post-processes. With the assistance of internet and Wi-Fi, printing enterprises can provide cloud-based printing services, enabling customers to upload their files to a cloud-based platform and print them remotely. This service is particularly beneficial for customers who require printing capabilities while traveling or working remotely. By leveraging cloud computing, printing companies can optimize their printing, data management, and storage processes, thereby enhancing overall efficiency and productivity.

EDI and API

The use of Electronic Data Exchange (EDI) allows for the smooth transfer of data between companies. Partners exchange files directly with one another. It is understood that EDI will be used to process orders, order confirmations, delivery notes, and similar documents, so there is no need to create, print, send, fax, or email these documents manually. Electronic Data Interchange (EDI) automates the exchange of data in a common format between businesses. It eliminates delays caused by manually processing data (like creating documents), transferring data (like sending mail), and entering data back into the partner system (e.g. typing). APIs allow for the real-time integration of a wide variety of

external data sources that are useful for demand forecasting (and more sophisticated techniques, such as demand sensing). To facilitate integration, such APIs might be documented in a standardized fashion.

Web services

Web services are a way for electrical devices to communicate with one another over the internet. Web services allow automating interactions through cooperative commerce in the case of printing by integrating the internet with corporate processes. With this technology, new programs can be created to address corporate issues.

Blockchain

Printing applications for blockchain have the potential to provide visibility and traceability throughout the supply chain, safeguard products, and promote product authenticity. Maintaining confidence between printing enterprises and suppliers is facilitated by blockchain-based tracking. The distributed ledger technology (Blockchain) is an encrypted system for exchanging data and documents and spotting payment fraud.

Data Analysis

Simulation

In order to analyze how modifications to existing operations will affect production, simulation in production is utilized to generate models of facilities and networks. This method supplies the dynamic information required to expand and redesign various components within the current production network.

Data Mining

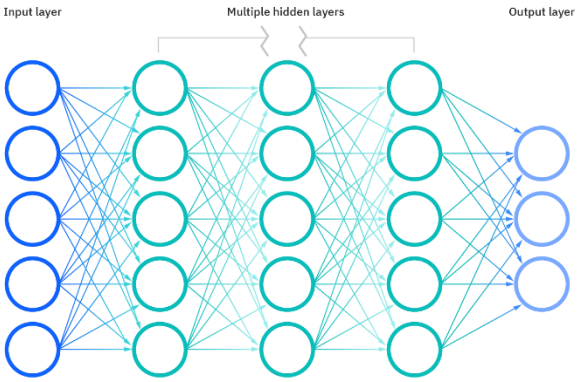
The practice of extracting useful information from unprocessed data is commonly referred to as data mining, and it is a technique that has been adopted in the printing industry to enhance operational visibility and streamline processes. By leveraging business intelligence tools, data mining techniques can be applied to comb through vast databases, identify significant trends and patterns, and provide developing firms with valuable insights in a readily actionable format.

Artificial Intelligence (AI)

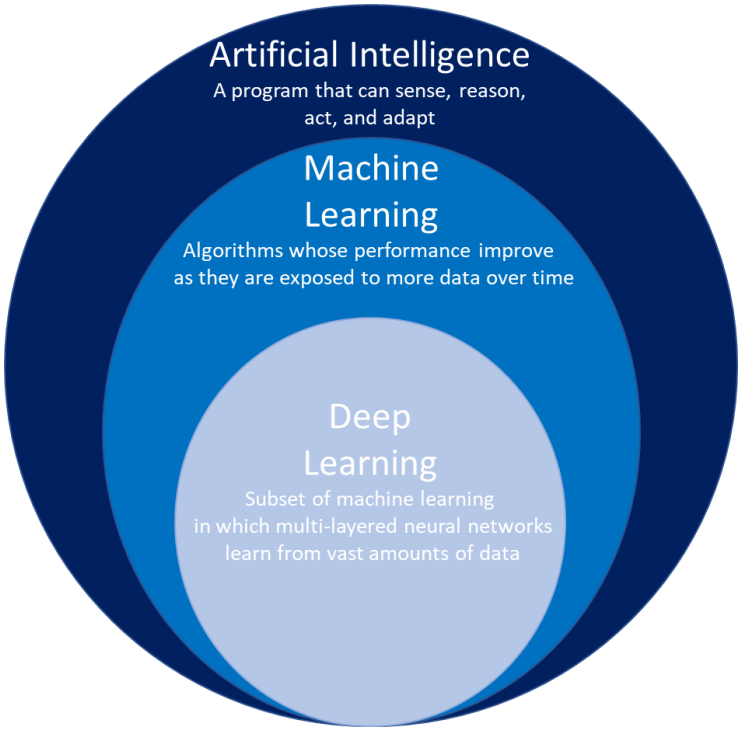
The advent of the internet has revolutionized the way business's function, providing them with access to a worldwide audience and significantly enhancing communication efficiency. This has given rise to novel business models, including e-commerce, which enables companies to sell their goods and services online. Furthermore, the internet has facilitated the trend of remote work, allowing employees to work from any location across the globe. Overall, the internet has had a profound and transformative influence on modern business operations.

Machine Learning

Printing manufacturers face significant challenges in managing their operations smoothly due to the volatility associated with their partners. Nonetheless, machine learning models can help to mitigate such risks by offering valuable insights from large data sets, thereby making the value chain more resilient and reducing uncertainties. Specifically, these models can improve demand prediction accuracy, enhance the supply chain's ability to cope with disruptions, and enhance the sustainability of manufacturing costs.



With use of massive number of data sets, the value chain can be enhanced by efficiency improvement, maintenance necessities prediction, quality control, and costs reduction. By analyzing data involved, printing company can optimize their production flows, reduce waste, and along with offer personalize products and services accordingly. Customers expect faster response times from digital services. Large volumes of data are produced through online sales and client interactions, which can then be processed further to create new tactics. Historical data is present in enterprise systems and can be used to improve operations. Thus, a production digital twin is vital to be created for actual application in printing processes. Printing workflow can be simulated and optimized with identifying inefficiencies and bottlenecks involved and therefore feasible to improve overall productivity and efficiency. In parallel, digital twin of printing equipment enable to monitor and analyze data collected for distinguishing patterns and predicting maintenance needs. It will also help to perform preventive maintenance, reducing downtime plus increasing equipment lifespan and utilization.


Artificial Intelligence
A program that can sense, reason, act, and adapt
Machine Learning
Algorithms whose performance improve as they are exposed to more data over time
Deep Learning
Subset of machine learning in which multi-layered neural networks learn from vast amounts of data

Output and HMI

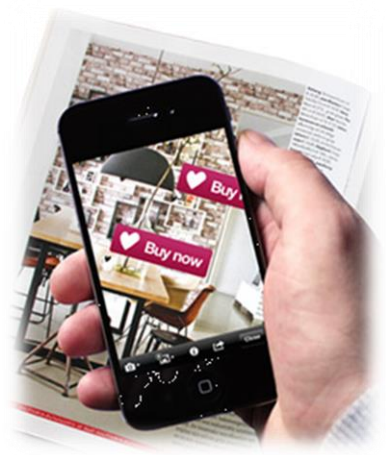
Robotics and Mobile System

Businesses have been utilizing automation and robotics for a considerable amount of time. The latest generation of robots are intelligent and self-sufficient machines that can carry out tasks without human supervision. In the printing and warehousing industries, various types of robots and machines, such as drones, autonomous vehicles, and mobile robots, are commonly used. In warehouses, robots and collaborative robots (cobots) are used for handling materials, including picking, sorting, and packaging. AGVs provide flexibility in material transportation, while drones are well-suited for inventory checks and last-mile deliveries.

Wearables, Virtual Reality (VR) and Augmented Reality (AR)

Exoskeletons are used to help workers perform tasks that are challenging to do ergonomically, while mobile devices such as smartwatches and glasses provide added information for non-traditional tasks. Wearables are devices that provide continuous guidance and support to employees, giving them extra contextual information. Virtual reality creates a simulated environment that replicates real-life settings, making it useful for employee training in warehouse environments. Augmented reality can be used to optimize warehouse space and enhance order picking by employing 3D warehouse architecture, as well as locate and extract goods.

Integrated HMI Systems



In designated stations, station-based help systems (such as pick-by-light, lean working stations, control rooms, and line displays) can help by providing pertinent information or by simplifying challenging jobs. A control room offers a centralized perspective for production planning and management. Important KPIs are visualized using line displays to aid in decision-making. Integrated HMI also offer the feasibility of monitor the printing processes in real-time and adjust necessary conditions quickly. One of the common HMI system is Machine Control Panel which provide a centralized control interface for managing printing equipment and processes such as adjusting printing settings, monitoring ink levels, and controlling material feed rates. Augmented Reality (AR) is another technology can be used in shopfloor to enable operator real-time information and guidance. AR systems can overlay information onto the operator's field of view as well as the instructions on how to perform specific tasks or identifying potential issues. In case any potential inefficiencies, product deviation, waste, malfunctions, harm or accidents found, operators are allowed to aware, fine-tune, and resume accordingly.

IT Systems

In order to provide digital assistance for manufacturing-related tasks along the supply chain, both internally and externally, information technology (IT) systems are used. Commonly used IT systems include Customer Relationship Management (CRM), Order Management System (OMS), Supplier Relationship Management (SRM), Enterprise Resource Planning (ERP), Warehouse Management (WMS), Transportation Management (TMS), and Manufacturing Execution System (MES). These technologies enable the creation of an interconnected, automated, and open supply chain of goods and services. By integrating these technologies, the manufacturing industry can meet and exceed customer expectations, as well as explore new markets for business growth.

9 Vendor Landscape

The following vendors were identified to provide digital solutions for driving Print 4.0. These vendors induce various technology regarding to printing industry as well as overall all production management which can be categorized into three main area of operation: Smart Factory Solutions – end-to-end shopfloor digitalization, Digital Innovation – innovative solutions for print technologies and IoT Applications – machine connectivity and data visualization. HKSMEs could take these global vendors as a benchmark and good practice for local digital solutions for driving Print 4.0.

Smart Factory Solutions – End-to-end Shopfloor Digitalization

1. Heidelberg machines – Prinect solution

Heidelberg machines equipped with the Prinect system facilitate machine and production data gathering. It offers a smart print shop solution for commercial, packaging, or label printing, as well as a one-stop shop for online portals, automation, machine data gathering, and business analytics. Prinect Production can entirely digitize a print facility. It automates production, color, and quality control, as well as providing critical data for research and reporting. Customers are more likely to return to a print shop that has an intelligent process.

2. Bobst (Switzerland) – BOBST Connect

Bobst(Switzerland) is a leading suppliers of substrate processing, printing & converting equipment and services for the label, flexible packaging, folding carton and corrugated industries. BOBST Connect is a fully connected all-in-one digital platform. It is single solution for all packaging printing processes including pre-press, production, optimization, maintenance and market. Bobst Digital cloud platform is able to connect physical production equipment with digital solutions through state-of-the-art IoT technology to enable faster resolution and reduced downtime.

3. HP Indigo – PrintOSx Solution

HP Indigo developed the innovative PrintOSx Solution as a solution for use in Print Factories. It is a collection of software programs that can be used for any and all business processes. These applications

cover three primary categories: power people, data-driven decisions, and high-value opportunities. In addition, these are partner solutions for HP Indigo presses used for printing labels and packaging.

Digital Innovation – Innovative Solution for Print Technology

1. Fujifilm Germany – Platesense

Platesense from Fujifilm Germany manages plate production efficiency, resulting in cost savings. Fujifilm not only provides the plates when you need them, but they can also handle your waste and aluminum collection, as well as service and maintain your processor. They also provide CTP equipment leasing programme and equipment swap-out programme which removes the capital expenditure required to update or invest in a new platesetter, and gives a predictable and controllable cost.

2. Highcon

Highcon offers innovative solution for cutting and creasing – digital cutting and creasing technology. Creasing is carried out by the Highcon patented Digital Adhesive Rule Technology(DART). The crease produced is visually different to the conventional crease but functionally performs as well or better. Having this kind of digitally driven mechanical creasing gives high quality results with precision and accuracy.

3. Landa (Israel) - NanoInk

Landa NanoInk introduces digital prink ink technology – Nanography. Nanography enables ink pigments reduced to nanometric scale. It can provide precise ink lay-down compared to Inkjet printers. Nanography is able to produce a greater light dynamic range because the pigments used in Landa NanoInk® have a size that is both extremely small and consistently small. The CMYK color palette used by Landa covers 84% of the Pantone color space, which is 30% larger than the CMYK offset color palette.

IoT Application – Machine Connectivity and Data Visualization

1. Koenig & Bauer (KBA) - VisuEnergy X

Koenig & Bauer(KBA) offers an Energy management system called VisuEnergy X for printing and packaging industry. EnMS reads meters, data loggers, and IoT sensors via all common APIs, scalable and expandable with more sensors. The mobile app collects non-connected meter data manually. Several pre-defined diagram types illustrate energy data flows. The solution also features a dashboard builder for quick production of personalised analysis. VisuEnergy X is the only solution on the market that also permits the development of industry-specific key figures dependent on the printed output. The platform monitors and documents energy data continuously, enabling successful energy management. A look at consumption patterns and specific consumers reveals where the greatest savings potentials are located. Comprehensive reporting and export capabilities ease documentation for customers, end consumers and legislators. The EnMS securely stores measurement data for later retrieval.

2. Koenig & Bauer (KBA) - Kyana

Other than VisuEnergy X, KBA also introduces innovative AI technology called Kyana. Managed Services monitors all alphaJET system functions 24/7 and informs you via the dashboard. Performance evaluation reveals printer availability. Using the analysis allows optimizing the performance and hence entire production in a verifiable and traceable method. Remote access is also available for fast and qualified support. This enables to check functions, set parameters, pre-qualify for troubleshooting, and take immediate action which expedites expert support and eliminates costly service calls. Advanced dashboard displays consumables and article numbers. With a dashboard link to webshop, ink and solvent can quickly and easily be reordered.

3. Komori (Japan) – KP-Connect

Komori (Japan) created the KP-Connect system, an IoT-based cloud solution for data visualization and gathering information on breakdowns, changeover times, printing efficiency, and idle times. The KP-connect dashboard provides a comprehensive real-time view of production processes and

communicates extensive press operating information in a secure, cloud-based environment. The printer's own enhancements are given, as well as data-driven press and process improvement strategies from Komori.

10 Best Practices

Flyeralarm - Europe's largest B2B online printer

Flyeralarm is a success story that highlights the impact of Industry 4.0 on the printing industry. From its humble beginnings as a start-up, Flyeralarm has grown to become one of Europe's leading online printers in the B2B sector. The company's business concept is based on Industry 4.0, which allows it to offer competitive prices through smart production. This approach has made it possible for Flyeralarm to produce flyers, brochures, and many other printed goods faster, cheaper, and with the same quality as in conventional print shops.

Digitalization and business model optimization are at the forefront of Flyeralarm's operations. The company's digital business model provides a wide range of products and services available digitally, serving a variety of branches. Moreover, Flyeralarm employs efficient and digital processes in sales and production. From the first customer contact until the job order is started at the machine, all processes are fully autonomous. Customers can place orders via the webshop, and a software check determines if printing is possible. The job is then assigned to a print plate, with hardly any manual intervention necessary. With autonomous processes, Flyeralarm can print three times more than before. In the future, customers will have the ability to edit the material directly in the web tools using the templates they have developed.

Flyeralarm's commitment to innovation is evident in their recent foray into augmented reality (AR) services. The company now offers an AR service for small and medium-sized companies, allowing customers to experience products, services, and other content digitally via smartphones and tablets. This innovative approach demonstrates the company's willingness to embrace emerging technologies and stay ahead of the curve.

Flyeralarm's success is a testament to the power of Industry 4.0 and digitalization. Their efficient and autonomous processes, coupled with their commitment to innovation, have enabled them to grow from a start-up to a global player in the printing industry. With a digital business model and a focus on optimizing their processes, Flyeralarm is well-positioned to continue leading the way in the printing industry for years to come.

Giesecke+Devrient – Security printing solutions

Giesecke+Devrient (G+D) was founded in Leipzig in 1852 which is a global industrial group that specializes in security paper production and banknote printing. Over the years, the company has expanded its offerings to provide solutions around cash, including printing machines, security technologies, and software solutions for avoiding counterfeits and ensuring the quality of banknote production. G+D has implemented a digital workflow system that streamlines the production process by automating tasks such as job setup, artwork approval, and quality control. This high-tech printing process and quality inspection utilize the BPS X9 solution from G+D, which inspects individual

banknotes at top speed for optical and machine-readable features. Any banknotes with quality defects are immediately destroyed, and no manual intervention is required in the quality inspection process.

Policy for Sustainability

In addition to their innovative and efficient processes, G+D is committed to sustainability. They have a comprehensive strategy and clear goals regarding sustainability, with a dedicated Corporate Sustainability unit that addresses all ESG matters. To reduce their ecological footprint, G+D is actively engaged in environmental topics. In 2021, the company made a decision to achieve net-zero greenhouse gas emissions by 2040.

G+D is also taking steps to produce their own regenerative energy at select locations like Louisenthal, Malaysia, and Athens. This approach not only reduces their carbon footprint but also helps to ensure a reliable and sustainable energy supply. Moreover, G+D is utilizing AI to improve the efficiency of its manufacturing processes by adjusting ink settings based on the substrate and other variables.

Giesecke+Devrient is a global leader in security paper production and banknote printing, providing solutions around cash that include printing machines, security technologies, and software solutions for avoiding counterfeits. With their innovative and efficient processes, commitment to sustainability, and utilization of AI, G+D is well-positioned to continue to lead the industry in the years to come.

Huhtamaki

Huhtamaki is a producer of flexible packaging solutions and an experienced specialist in pre-press and print plate manufacture, offering a one-stop-shop for all printing services, including consultation, profile creation, print plate manufacturing, gravure cylinders manufacturing, and sleeve manufacturing. The company has implemented several innovative solutions to optimize its production processes and reduce its environmental impact.

Huhtamaki has implemented an AI-powered system for production planning and scheduling, which predicts the quality of paperboard used in its production processes, allowing it to optimize the process parameters and minimize waste. The company is also using IoT sensors to monitor its production processes and equipment,

enabling it to identify and resolve issues quickly. For example, the company has implemented an IoT system that monitors the temperature and humidity levels in its paper mills, allowing it to optimize the production process and reduce energy consumption.

Huhtamaki has also created a digital twin of its paperboard production line, which allows it to simulate different scenarios and optimize the process parameters to reduce waste and increase efficiency. The company is committed to minimizing the environmental impact of its products and operations and has set several ambitious sustainability targets. These targets include reducing greenhouse gas emissions by 15% per unit of net sales by 2025, achieving 100% renewable electricity by 2030, increasing the use of recycled content in its products to 60% by 2030, and eliminating all fossil-based plastic raw materials from its products by 2030.

To achieve these targets, Huhtamaki is investing in sustainable materials, such as renewable and biodegradable packaging, and implementing circular economy principles, such as designing products for reuse and recycling. The company is also working closely with its suppliers, customers, and other stakeholders to drive sustainability throughout its value chain.

In conclusion, Huhtamaki is a leading producer of flexible packaging solutions and an experienced specialist in pre-press and print plate manufacture. The company is committed to minimizing its environmental impact and has implemented several innovative solutions to optimize its production processes and reduce waste. With its ambitious sustainability targets, investment in sustainable materials, and focus on circular economy principles, Huhtamaki is well-positioned to lead the industry in sustainable packaging solutions.

11 Recommendations for Print 4.0 Implementation in Hong Kong

Recommendations were derived both for individual small and medium-sized enterprises (SMEs) and for the general setup of shipping and printing companies in Hong Kong in order to enable the deployment of Print 4.0 and to take the following steps in the process.

General recommendations for Printing companies

- Even in productions where more advanced technology is not an option, even the most fundamental forms of digitalization can help detect waste and inefficiencies. Before beginning the process of digitization, however, the processes themselves need first be systematized (that is, the LEAN approach should be implemented).
- Controlling the availability of critical machines (also known as bottlenecks) and evaluating the amount of time spent waiting for and setting up these equipment should be the primary focus. During optimizations, necessary materials might be prepared by giving digital instructions to workers in advance. This might be one example.
- There is room for improvement across the board with digital processes, beginning with pre-press and continuing through printing and post-press. Eliminating paper-based order processing can increase utilization while also reducing administrative costs and the amount of time wasted.
- Once LEAN management has been implemented and structured process mapping has been completed, it is easier to determine which critical metrics and process steps entail waste and ought to be digitalized. This is because the identification of waste is facilitated by the structured process mapping. In the majority of the cases that have been observed, it is not recommended to place emphasis on machine details or process details, both of which require pricey software or retrofitting. Instead, it is recommended to place emphasis on fundamental value stream visualization with straightforward digital support (for example, digitally tracking times of operation and waiting of a machine, tracking times of processing and waiting of an order, tracking times of personnel usage), rather than detailed process parameters.
- The majority of the identified bottlenecks have occurred in the post-pressing procedures. These processes are frequently still carried out in a very manual manner, and it would be worthwhile to investigate whether automation of processes such as feeding for binding

would remove bottlenecks from the overall process and have a positive return on investment due to the amount of time that would be saved.

- The ability of most observed companies to be flexible in meeting the requirements of their consumers is a crucial differentiating element that explains why customers should favor SMEs. In order to maintain this flexibility, it is not desirable to fully digitalize the flow of the process; rather, it is beneficial to support employees by, for example, decreasing the need for double input, information copying, and use of paper forms rather than comprehensive process management systems.
- The entirety of the sales process is still quite manual, and it is carried out by email. It also involves a significant amount of back-and-forth contact. The digitization of this process, the provision of improved information on product status, and so on could be of assistance with the acquisition of new customers. Keeping track of the status of manual manufacturing can be simplified with the help of cellphones, which can be an effective option (e.g. operators report via app, when production order is completed). It's feasible that this could be a solution for post-processing, where there are a significant number of manual operations, as well as printing, when getting access to this machine information isn't always available.

Recommendations for HKPA on association level / Printers on industry level

Bridging the Digital Skills Gap in Hong Kong Printing Factories

- The employees of printing factories should participate in a training program that teaches fundamental digital skills in order to boost the availability of skilled workers and increase staff acceptance of digitalization. This should not only target personnel at the management level or white collar positions, but particularly staff doing pre-press and setup work in addition to planners.

Building Affordable and Simple Process Management Solutions for Printing Factories in Hong Kong

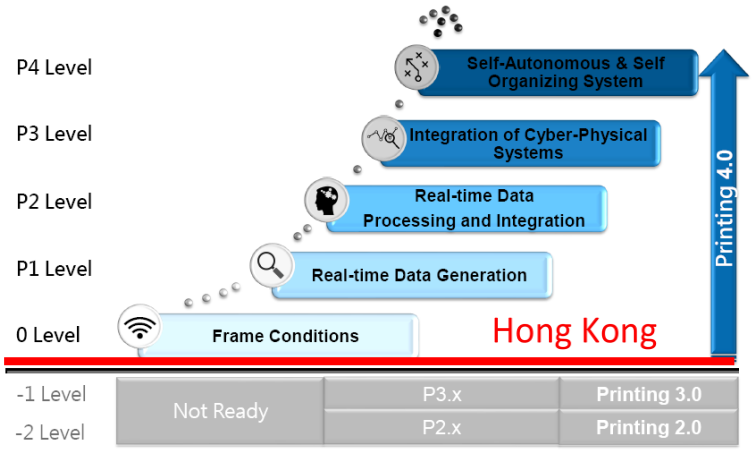
- The majority of printing plants require straightforward solutions, particularly for operation management. It could be helpful to have affordable solutions ready more rapidly if software companies were encouraged to produce solutions that are suitable for use by SMEs by pooling customers.

12 Comparison of Printing Industry in Germany and Hong Kong

Hong Kong

The printing industry has been undergoing a digital transformation over the past decade, with a growing use of digital printing technology and the use of data and automation to optimize production processes. This has resulted in an increase in the overall quality of the printed product.

It is possible to conclude, on the basis of the evaluations that were carried out for the SME printing industry in Hong Kong, that SMEs have begun implementing digital technologies in order to enhance their business operations. Companies that were evaluated were at various stages of the digitalization process; however, a significant number of their procedures are still carried out manually, making it necessary to investigate the possibilities presented by Industry 4.0. As a result, the overall level of maturity can be judged to be somewhere between -1 and 0, which indicates that the conditions for implementing I4.0 are still being developed.



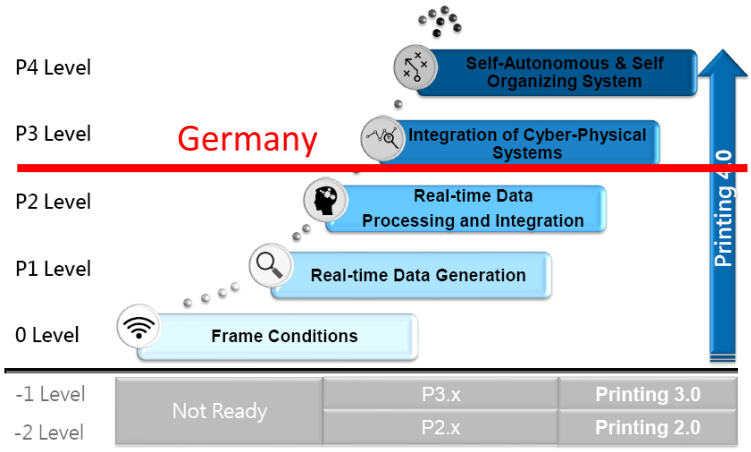
Certain businesses have been able to successfully implement Industry 4.0 through the use of value-based applications and have reached a higher maturity level between visibility (1) and transparency (2).

Germany

The degree to which different organizations have matured in terms of Industry 4.0 can vary greatly from one another, but the majority of printing companies in Germany are located somewhere in the middle of the levels visibility (1) and transparency (2). This indicates that data collection and data analysis are currently being utilized; however, sophisticated analytics and prediction in operational settings have not yet been utilized.

Some of the most successful businesses in the world have reached higher degrees of digitization and automation. organizations that adhere to best practices, such as Flyeralarm and Giesecke & Devrient, are further along in their road toward Industry 4.0 maturity. It is possible to estimate that these organizations have reached a level of maturity that falls between transparency (2) and predictability

(3). (The research that was done in order to locate vendors and best practices was used to make an estimate of the maturity level of Germany's printing businesses.)



13 Self-Assessment Manual and Road Map Quick Start Guide

In addition to the inter-sectoral road maps, a self-evaluation tools was also created and map to road map. The tools provides businesses with a means of objectively evaluating their own Print 4.0 development progress. To that end, we've compiled a set of questions across several dimensions taken directly from the Print 4.0 Navigator. Following the completion of the questionnaire, businesses are given a unique assessment score. This score helps the company locate itself on a cross-industry road map and provides a quantitative depiction of the current state of advancements related to Print 4.0. As a result, the next phase of the gradual transition to Print 4.0 can involve picking the most applicable use cases and actions from the roadmap.

A. Online self-assessment tools

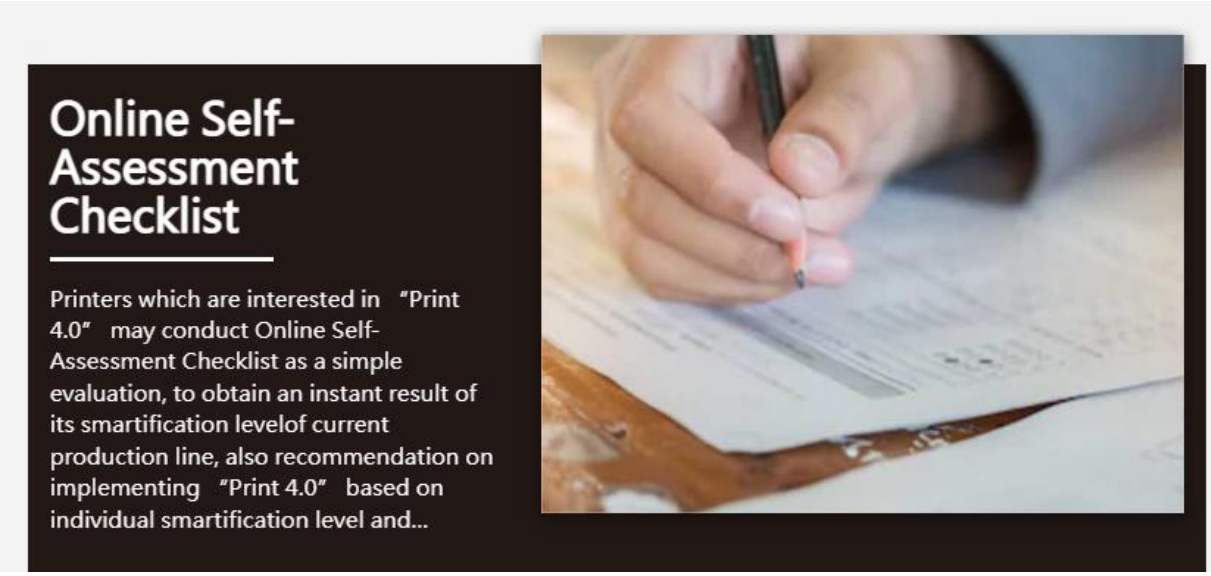
The self-assessment tools will be uploaded to official website of Print 4.0 after 2 June 2023, the link is as below:

Scan Here

http://print4_0.hkprinters.org/

1. Select “Project Result”

2. Scroll down and find Online Self-Assessment Checklist(After 2 June 2023)



B. Dimensions of the self-assessment

Data-driven Business Models - Innovative business models that involve data are developed, and improved with the help of data, and presented digitally to the customer.

Smart Services & Processes - Commercial functions, digital and value-added services offered to customers and processes in the company without a physical counterpart (e.g., finance, HR).

Smart Supply Chain & Operations - Operational functions, their interactions, and exchange between entities in the entire supply chain and processes in the company with physical counterpart (e.g., warehousing, intra-logistics).

Information Technology (Networks & Data) - Enabling technologies and IT infrastructure for data transmission and analysis as well as available IT systems.

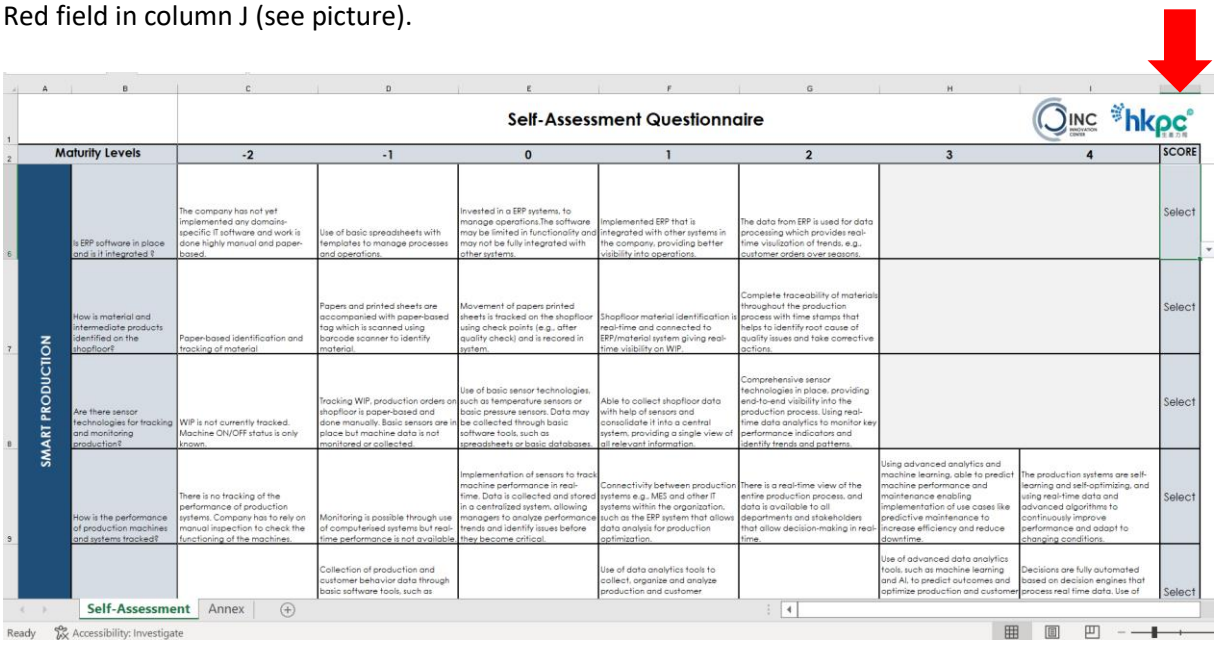
IoT (Sensors & Output) - Enabling IoT technologies for data generation about goods and assets in the supply chain.

Strategy & Organization - Defining a strategy for implementing Print 4.0 and creating conducive organizational structures.

Culture & Mindset - Culture and willingness in the company for collaboration among employees, the handling of data and utilization of digital tools to support decisions and execute processes.

C. Application of the Self-Assessment Tool

To use the self-assessment tool, users must answer questions 1-24. To do this, the answer that applies to the company must be chosen in the columns and the corresponding score must be selected in the Red field in column J (see picture).



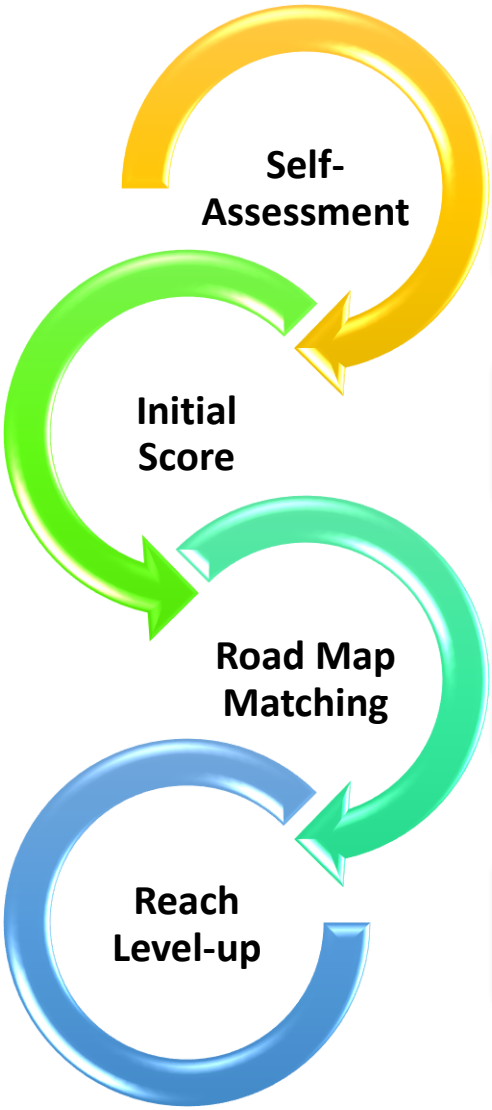
Self-Assessment Questionnaire

	Maturity Levels	-2	-1	0	1	2	3	4	SCORE
SMART PRODUCTION	Is ERP software in place and is it integrated ?	The company has not yet implemented any domains-specific IT software and work is done highly manual and paper-based.	Use of basic spreadsheets with templates to manage processes and operations.	Invested in a ERP systems, to manage operations.The software may be limited in functionality and may not be fully integrated with other systems.	Implemented ERP that is integrated with other systems in the company, providing better visibility into operations.	The data from ERP is used for data processing which provides real-time visulization of trends, e.g., customer orders over seasons.			Select
	How is material and intermediate products identified on the shopfloor?	Paper-based identification and tracking of material	Papers and printed sheets are accompanied with paper-based tag which is scanned using barcode scanner to identify material.	Movement of papers printed sheets is tracked on the shopfloor using check points (e.g., after quality check) and is recored in system.	Shopfloor material identification is real-time and connected to ERP/material sytem giving real-time visibility on WIP.	Complete traceability of materials throughout the production process with time stamps that helps to identify root cause of quality issues and take corrective actions.			Select
	Are there sensor technologies for tracking and monitoring production?	WIP is not currently tracked. Machine ON/OFF status is only known.	Tracking WIP, production orders on shopfloor is paper-based and done manually. Basic sensors are in place but machine data is not monitored or collected.	Use of basic sensor technologies, such as temperature sensors or basic pressure sensors. Data may be collected through basic software tools, such as spreadsheets or basic databases.	Able to collect shopfloor data with help of sensors and consolidate it into a central system, providing a single view of all relevant information.	Comprehensive sensor technologies in place, providing end-to-end visibility into the production process. Using real-time data analytics to monitor key performance indicators and identify trends and patterns.			Select
	How is the performance of production machines and systems tracked?	There is no tracking of the performance of production systems. Company has to rely on manual inspection to check the functioning of the machines.	Monitoring is possible through use of computerised systems but real-time performance is not available.	Implementation of sensors to track machine performance in real-time. Data is collected and stored in a centralized system, allowing managers to analyze performance trends and identify issues before they become critical.	Connectivity between production systems e.g., MES and other IT systems within the organization, such as the ERP system that allows data analysis for production optimization.	There is a real-time view of the entire production process, and data is available to all departments and stakeholders that allow decision-making in real-time.	Using advanced analytics and machine learning, able to predict machine performance and maintenance enabling implementation of use cases like predictive maintenance to increase efficiency and reduce downtime.	The production systems are self-learning and self-optimizing, and using real-time data and advanced algorithms to continuously improve performance and adapt to changing conditions.	Select
			Collection of production and customer behavior data through basic software tools, such as		Use of data analytics tools to collect, organize and analyze production and customer		Use of advanced data analytics tools, such as machine learning and AI, to predict outcomes and optimize production and customer	Decisions are fully automated based on decision engines that process real time data. Use of	Select

Depending on the maximum maturity level required for each query, the score ranges from -2 to between 1 and 4. Some questions are limited to "Visibility" level 1 because a higher score is either impossible or irrelevant for the query in question. The cumulative score is automatically calculated and displayed in field I1 after all questions are answered. The total score equals the lowest score across all dimensions, as in the context of digitalization, the weakest link determines the system and should therefore serve as a starting point for implementing use cases and making equal progress across all business areas and departments. Last but not least, the outcome can be used to determine the next stages and value-adding use cases for the transformation to Print 4.0 in conjunction with the corresponding roadmap for Printing services providers or the manufacturing and trading industry.

D. Quick Start towards Print 4.0

Here is a quick start guideline to operate your business within the framework of Print 4.0:



1. Use the Self-Assessment Tool mentioned in Part B, Section 14 provided in this document to evaluate your company in various dimensions along the value chain.

2. Obtain initial scores for each dimension to determine your company's level of maturity.

3. Map the result to the Road Map of Print 4.0 in Section 6 to identify the requirements for the level of maturity you aspire to achieve and the gap between current level.

4. To improve your score, review the detailed description of the action item in Section 7 and organize the implementation items to achieve the requirements.

By following these steps in each above, you can quickly get started with strengthening the digital capabilities of your company and achieve sustained success.

Sources Useful sources for vendors and use cases

A. Vendor Landscape

1. https://www.heidelberg.com/global/en/software/prinect_overview.jsp?gclid=Cj0KCQiAwJWdBhCYARIsAJc4idAQ6_ApxIy6YoUcJSJYiE-ec6Rluh1yiRXqUQ8DAQX9ToFJk5hSx1kaAm7BEALw_wcB
2. https://info.fujifilm.eu/PlateSense_UK.html?utm_source=referral&utm_medium=eu_website&utm_campaign=PlatesenseBrand
3. https://digitalisation.koenig-bauer.com/en/networking-processes/energy-management/visuenergy-x/
4. https://digitalisation.koenig-bauer.com/en/kyana/
5. https://www.bobst.com/deen/about-bobst/moving-forward/bobst-connect
6. https://www.youtube.com/watch?v=QUVhvjkorRc
7. https://www.komorisolutions.com/kp-connect/en/
8. https://www.komori.eu/products/ict-solutions/kp-connect-pro.html
9. https://www.komori-america.us/products/print-management-solutions/kp-connect/
10. https://www.highcon.net/white-paper/digital-cutting-and-creasing-the-science-behind-the-innovation/
11. https://www.highcon.net/wp-content/uploads/2018/01/Digital_Cutting_Creasing_The_Science_Behind_The_Innovation_Feb_2017.pdf
12. https://landanano.com/technology/landa-nanoink/
13. https://landanano.com/technology/nanographic-printing/
14. https://www.hp.com/us-en/industrial-printers/indigo-digital-presses/printosx-software-solutions.html

B. Best Practices

1. https://www.flyeralarm.com/de/
2. https://www.mc-mainz-wiesbaden.de/de/aktuell/detailansicht/news/flyeralarm-vom-start-up-zum-global-player/?tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=2644a6a4f78a14cfb3392c49ce2f65f6
3. https://www.beyond-print.net/interview-flyeralarm-status-quo-after-the-2016-reorganization/
4. https://whattheythink.com/news/63897-market-leading-online-printers-europe-print-genius-52uv/
5. https://www.youtube.com/watch?v=Mvr86EHqods
6. https://www.gi-de.com/
7. https://www.huhtamaki.com/en/sustainability/