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Logistics 4.0 Maturity Level Protocol for Manufacturing and Trading Industry

Contents

Editorial Board and Disclaimer

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1 Executive Summary

New challenges are constantly arising in supply chain logistics which calls for innovation. Emergence of new technologies are constantly creating disruptions which opens new business opportunities. Logistics 4.0 is a concept that helps in leveraging the power of these technologies to benefit the whole ecosystem and drive revenues. To adapt to these changing times, companies need to move towards digitalization. While the leading market players are busy innovating, the SMEs have also managed to enter the ground to make their processes smart and their decisions intelligent.

The term Logistics 4.0 is focusing not only on the logistical processes in the shipping and manufacturing sector, but rather it embraces technological use cases enhancing the full value-creation process of turning raw material into sellable goods and it does not stop there. A successful transformation requires the solutions, realized through technologies, to be aligned with both, the focus on the unique situation of the organization as well as with its culture and specific qualifications. The goal of Logistics 4.0, of becoming more flexible in the interaction with stakeholders and their shifting demands is required in the current situation while increasing resistance against unplanned disruptions.

This document is a guideline for every shipping company to implement Logistics 4.0. It contains a stepwise approach to attain higher levels of digital maturity. By addressing the current challenges and analyzing the opportunities of Logistics 4.0, a roadmap has been developed for shipping companies along with specific use cases. Additionally, a tool for self-assessment is provided for businesses to measure their current individual digital maturity regarding Logistics 4.0, to plan the company-specific roadmap and define value-adding pilot projects.

2 Introduction – Project Background

2.1 Motivation

The global pandemic, chip crisis, disrupted logistics networks and increasing compliance requirements pose unforeseeable challenges to global enterprises. Uncertainties and delays in global supply chains accumulate while consumer expectations on what can be done online and what can be delivered on short notice are steadily increasing. The resources that are not scarce or insufficient to meet the customer demand cannot be miraculously generated through digitalization and connectivity in global value networks. Still, digital capabilities help companies to create comprehensive transparency and react faster and better in uncertain and dynamic environments. The term *Logistics 4.0* describes the impact of Industry 4.0 on logistics and the interaction of Industry 4.0 technologies and paradigms with the cross-functional and inter-company functions and processes of logistics.

The digital connectivity and close integration of processes, assets, and entities in the supply chain, such as producers, vendors, warehouses, transportation companies, distribution centers, retailers and customers offers great potential for all stakeholders. Companies that continue to build their digital capabilities in logistics can, for example, minimize their costs through stronger collaboration, transparency about the status quo, increased automation, and higher efficiency of processes. On the other hand, companies have the opportunity to enhance customer satisfaction through increased delivery reliability, quality, flexibility and can explore growth opportunities through new digital business models.

2.2 Project Scope

To help HKSMEs companies to implement Logistics 4.0 and build stronger digital capabilities in the area of logistics, the Hong Kong Shippers' Council, together with the Hong Kong Productivity Council (HKPC) and international partners, initiated the project "Towards Logistics 4.0 - Preparing for The Next Stage Of Logistics In Hong Kong".

During the three major project phases from 2019 to 2022, more than 100 HKSMEs companies of the Shippers Council were surveyed on their logistics services and processes. In total, assessments with 22 selected pilot companies that fall into the categories of manufacturing companies with trading activities, trading companies without manufacturing activities, sea freight forwarder companies as well as cross border logistics companies were conducted to determine the status quo of logistics processes. Based on the gained insights, extensive roadmaps were developed to support companies in shaping the transformation to Logistics 4.0 and taking steps towards value addition Furthermore, international

conferences and seminars were held to share insights on the value, application fields and business model innovations of Logistics 4.0.

2.3 Introduction of the Entities

Shippers Council

The Hong Kong Shippers Council was established in 1967. The council consists of 15 trade associations and serves to protect and promote the interests of Hong Kong exporters and importers, traders and manufacturers in any issues relating to the transportation of merchandise by sea, land, and air. The Shippers Council represents Hong Kong shippers globally and shapes the regulatory environment on issues relating to the shipping and transportation of goods on a local, regional, and global level together with other regional and international organization.

Hong Kong Productivity Council (HKPC)

The Hong Kong Productivity Council (HKPC), established in 1967, is a multidisciplinary organization, which is tasked to promote productivity excellence in the Hong Kong industry sector and assist Hong Kong enterprises through the introduction of advanced technologies and innovative service offerings. HKPC focuses on topics such as IoT, big data analytics, AI, robotics, digital manufacturing, etc., to help companies to increase competitiveness in local and international markets, improve productivity, and reduce operating costs.

Fraunhofer IPT

The Fraunhofer society is a German research organization and the largest organization of applied research in Europe. Fraunhofer IPT, located in Aachen, is part of the largest cluster of production technology institutes in Europe. This cluster is formed together with renowned institutes at the RWTH Aachen Campus and is conducting research on providing connected, adaptive production solutions in Industry 4.0 for companies of all sizes.

INC Invention Center

INC Invention Center is a spin-off of Fraunhofer IPT and bundles know-how from various Fraunhofer and research institutes. It is headquartered at RWTH Aachen Campus and offers professional consulting and implementation services by helping companies become leading innovators through profound expertise in the fields of Industry 4.0, AI in production, sustainability as well as innovation and technology management.

In the project at hand, INC Invention Center as implementation agent was responsible for conducting the cross-industry survey of companies as well as the assessments of the selected pilot companies

together with the HKPC. Based on this, INC developed roadmaps to provide Hong Kong companies with actionable recommendations for their transformation to Logistics 4.0.

3 Introduction to Logistics 4.0 & Industry 4.0

3.1 Industry 4.0

Industry 4.0 is hailed as the fourth industrial revolution and constitutes a fundamental transformation of industrial value creation through the emergence of flexible, highly dynamic, and globally connected value networks. For companies, the vision of Industry 4.0 is to transform into a learning, agile enterprise that can adapt to volatile markets and dynamic environments by quickly responding to changing conditions. Industry 4.0 goes beyond automation as it enables the transmission, processing, and value-added use of the increased amount of collected and generated data that is available.

For enterprises, Industry 4.0 offers new opportunities to find value and capture it. Either companies can increase growth and revenue by introducing data-based business models, developing smart products, or offering data-driven services. On the other hand, costs can be reduced by increasing efficiency and flexibility, saving time, or improving quality of products and services. Hence, Industry 4.0 is not an end in itself, but enables companies to grow or improve operations supported by modern information and communication technology (ICT).

Technology Enablers of Industry 4.0

From a technology perspective, the revolutionary aspect lies in the ability of multimodal ad-hoc networking for communication and information exchange of people and cyber-physical systems in real time. Data consistency along the value chain is enabled by the so-called “single source of truth” concept, which essentially describes the practice of structuring data and information in a redundance-free manner to circumvent contradicting data sets and ensure a reliable basis for data analytics applications. The integration of modern sensor technologies and ICT in physical assets, the interconnection of people, systems and devices via the Internet of Things (IoT), analytics capabilities and a variety of assistance systems to provide data-based insights to users are the main technology enablers and central contributors to bringing intelligence to the full value chain.

3.2 Logistics 4.0

The connection of people and cyber-physical systems for the communication and exchange of data as well as the progression of the internet from an information source to the Internet of Things and Services also have significant consequences for the logistics sector. The technological enablers of Industry 4.0 offer great potential in terms of transparency, speed, flexibility, and manageability of logistics processes and are transforming the logistics sector toward the next stage of evolution: Logistics 4.0.

For logistics, digitalization enables an interactive flexibilization of business models, processes, and partner networks. In a narrower sense, Logistics 4.0 encompasses the linking and integration of internal and external logistics processes of companies and production facilities along the entire value chain to create decentralized and real-time logistics networks. Ultimately, Logistics 4.0 is not only about creating a digital supply chain for individual companies, but about connecting various value and supply chains of global company networks.

All elements and entities in the network, such as IT systems, humans, assets, and goods are connected via the internet and can communicate with each other. Humans can for example send data to the network via smartphones or tablets and materials or goods can be equipped with beacons to send data about their location or condition. Other elements are, for example, IoT devices with an inherent intelligence to autonomously perform tasks of different complexity, such as handheld devices, cameras, detectors, or self-navigating vehicles.

Benefits of Logistics 4.0

The goals of Logistics 4.0 are inter-company optimization and automation of material flows and resource utilization in both inbound and outbound logistics. Companies that are building more digital capabilities in the context of logistics can create significant competitive advantages by reducing their costs and at the same time increasing customer satisfaction by improving service quality and minimizing delivery errors. Among other things, Logistics 4.0 creates value for companies in terms of:

Name	Description
Delivery reliability, quality, and flexibility	Delivery reliability is enabled through end-to-end tracking of items and assets, prediction of bottlenecks and delays and identification of risks. Higher quality of goods and services is achieved through condition monitoring of goods and monitoring of processes in real time. Flexibility can be increased based on capabilities to adapt to dynamic environments and suggest alternative routes or scenarios.
Increased transparency	The integration of entities and logistics processes along the entire supply chain creates comprehensive transparency and thus facilitates supply chain management and supports decision-making.
Automation of processes	Progressing digitalization and connection also facilitates partly or full automation. For example, processes or workflows can be supported or even fully automated by using robotic process automation (RPA), or cargo itself could become intelligent and organize its own transport autonomously.
Enhanced collaboration	The connection of entities in the supply chain enables a higher division of labor and efficient collaboration with partners, suppliers, and customers.
New services & business models	The extensive collection of data throughout the supply chain enables data-driven and platform-based business models with new types of revenue models and new ways of service provision to the customer, such as SaaS models (Software as a Service).

Table 1: Value of Logistics 4.0

Evolution from Logistics 1.0 to Logistics 4.0

Figure 1: Evolution of Logistics

Due to the lack of digital technologies, traditional logistics is less efficient, highly manual, and requires centralized and complex planning. Typical characteristics are paper-based documentation, manual input, and transfer of data between IT systems, scanning of documents and constantly making phone calls to update the latest cargo status. These characteristics illustrate the procedures of traditional logistics and reflect the current status quo of many companies.

The evolutionary stages from Logistics 1.0 to Logistics 4.0 over the course from the 19th to the 21st century can be described as follows:

Stage	Logistics 1.0: "Local logistics"	Logistics 2.0: "Region centric logistics"	Logistics 3.0: "Global logistics"	Logistics 4.0: "Interconnected global logistics"
Content	Mechanization of transport from animal force to the operation and utilization of railways and own vehicles.	Higher complexity for logistics due to a growing logistics sector and routes focusing on inter- and intra-regional clusters and large-scale utilization of equipment (e.g., trucks, ships, aircraft).	Strong involvement of 3rd party logistics service providers, as companies inevitably do not have a fleet available everywhere and in sufficient numbers. Transport remains an intermediate step in the client's business process.	Independent automated control of logistics across the entire business process of companies and collaboration between logistic enterprises - logistic customer service as a priority.

Table 2: Evolutionary stages of Logistics

3.3 Challenges and Opportunities of Logistics 4.0 for Hong Kong

Observed challenges in Logistics 4.0 for Hong Kong SMEs

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

Independent introduction of Logistics 4.0

SMEs often do not have the skills themselves to implement Logistics 4.0, especially in shipping. Manufacturing companies have to some extend already established teams who have built digital production applications and are now also working on logistics 4.0 applications. Most IT staff is focused on commercial IT systems like ERPs or very specific IT solutions to digitalize individual processes. In this context, operational and business model improvements are left behind. Here, more knowledge on IoT applications and a more process-oriented thinking need to be promoted.

Standardization of interfaces

Interfaces are not standardized. Every new vendor and value partner has to be integrated, which often requires considerable effort or may not be even possible due to technologic or organizational constraints. If time and costs do not bring sufficient savings, integration might not be worthy.

Utilization of classic and manual communication methods

Many customers are still used to make use of e-mail or even fax/telephone for communication. Companies see themselves confronted with the question why they should digitalize if their customers do not insist to do so or even lack the capabilities to work together through new digital means. However, a generation shift at customers can quickly turn this around from API integration being not desired to being absolutely mandatory for maintaining business relationships. Thus, it is recommendable for companies to act proactively and already encourage their customers to benefit from the utilization of digital solutions and digital integration today.

Missing proactive approach towards driving Logistics 4.0 implementation

Consumer-facing companies innovate faster and adapt to changing market demand more rapidly. Individualization and connection to platforms like Amazon, Taobao, T-Malls, JD.com drives internal digital capabilities. For many, this is a big challenge at the beginning, but once they have achieved it, it helps drive the overall digitization of the company. Observations in industry show that many companies stop at that point and digitalization is driven to exactly the point where it's needed to interoperate with platforms and rarely further. However, companies should take the opportunity to analyse what additional benefits could be achieved by improving their digital maturity and in which areas further action should be taken to, e.g., streamline operations, optimize processes, or develop data-driven business models for leverage competitive advantage.

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

The opportunities of Logistics 4.0 for companies in the GBA and ASEAN region are divided into two groups and highlight below:

First, companies who do business in the GBA and ASEAN region to serve global customers with manufactured goods from the GBA or ASEAN region and then deliver to customers globally. Here, Logistics 4.0 can create business opportunities with regards to two main aspects:

1. With higher volatilities in supply chains and increasing compliance regulations imposed by governments worldwide, transparency and real-time tracking of shipments become clear Unique Selling Point (USP). Currently, many global customers (e.g., in Europe, the Americas, Middle East) make daily phone calls to ask suppliers about the exact position of their expected deliveries, e.g., whether it is on the ship, way, or how long it will still take. Providing this information in a digital form facilitates quicker and more adequate reactions. Thus, it saves costs for customers as the whole planning process from procurement over production to delivery can be adapted to the current situation.

2. In addition, the mentioned compliance requirements both in terms of CO_2 footprint and documentation of quality parameters can be significantly improved by automatic documentation and including features that allow a tracing of the full supply chain. For example, the capability to collect data on goods vibration to find the root cause for quality defects before the component is shipped to the customer or localization to determine the exact position of shipments can lead to a competitive advantage and are already being demanded by customers around the world.

The development of these capabilities throughout companies in the supply chain is only progressing slowly. But eventually, every supply chain's tier will need to be able to handle this.

Secondly, for companies who are serving the GBA and ASEAN consumer markets, Logistics 4.0 can also create business opportunities with regards to two aspects:

1. Customers in these markets are already acquainted to very fast deliveries and tracking of deliveries through apps like Amazon, T-Malls, Taobao or others. To satisfy these requirements, companies anyway have to build the infrastructure to connect to these platforms and shouldn't stop once they reached that milestone. Instead, they should use the newly acquired knowledge and skills to optimize their own internal processes and further develop their business models to differentiate from competition, e.g., via customer segmentation into those who prefer more simple and cheaper services and those who are willing to pay more for higher value services based on the analysis of customer data.

2. Besides the right pricing, flexibilization, speed and customization are the most important customer demands in this market. Companies should pursue business model innovation to offer matching goods and services that satisfy these demands. Here, logistics plays an integral role, as the more customization can be done in logistics, the more efficient the production can still be. Huge manufacturing organisations usually have complex defined processes for changes and bringing flexibility in any processes likes logistics has a long decision-making process due to the dependencies inside the organization. This is a key advantage of SMEs over big enterprises who can adapt faster.

4 Reader's Guide

In this document, a methodological approach towards Logistics 4.0 for the readers is introduced to understand the concept of Industry 4.0 and Logistics 4.0. This research highlights the challenges faced by the industries in Hong Kong and further explain the opportunities that are emerging. Various approaches such as surveys, assessments and market research have been followed to analyze the current conditions of the manufacturing and trading industry qualitatively and quantitatively based on which the key insights are derived.

The roadmap is specifically designed for the manufacturing and trading companies to attain Logistics 4.0 maturity levels and it displays use cases that prove beneficial for improving the index score. Further the use cases are defined in detail to understand the exact application premise. The roadmaps are designed such that there are investment efforts in each dimension before moving to next level. It is therefore advised to approach the roadmap one level at a time. Further the use cases in the roadmap have been briefly defined.

Best practices of some of the world leading logistics companies provide knowledge of advances in the industry.

Finally, this document comes with a self-assessment tool to conduct a checkup at your company for measuring digital maturity index and plan investment for digitalization in suitable pilot projects.

5 Methodology

A. Assessment and Roadmapping Approach

HKPC and INC Invention Center conducted a total of 22 pilot assessments to gain a comprehensive overview about the status quo, existing challenges and next actions in the area of logistics in Hong Kong enterprises. To observe the maturity of Logistics 4.0 applications in logistics processes, interviews with the top management and relevant departments were conducted. For the visited departments and observed processes, multiple points from a portfolio of 150+ questions in 8 dimensions were considered and evaluated. The assessment structure and maturity level logic is based on the Logistics 4.0 Navigator developed by INC Invention Center, Fraunhofer IPT and HKPC as well as the Hong Kong Logistics 4.0 Maturity Model, which is derived from the Acatech Industrie 4.0 Maturity Index developed by German academic research organizations.

B. Logistics 4.0 Navigator

For a structured approach to the field of Logistics 4.0 and the conducted assessments, the Logistics 4.0 Navigator was developed. The navigator serves as a framework to depict the interaction of a unique business model (Uniqueness), technology-driven applications that implement the business model (Application) and the underlying technologies that enable these applications (Enablers).

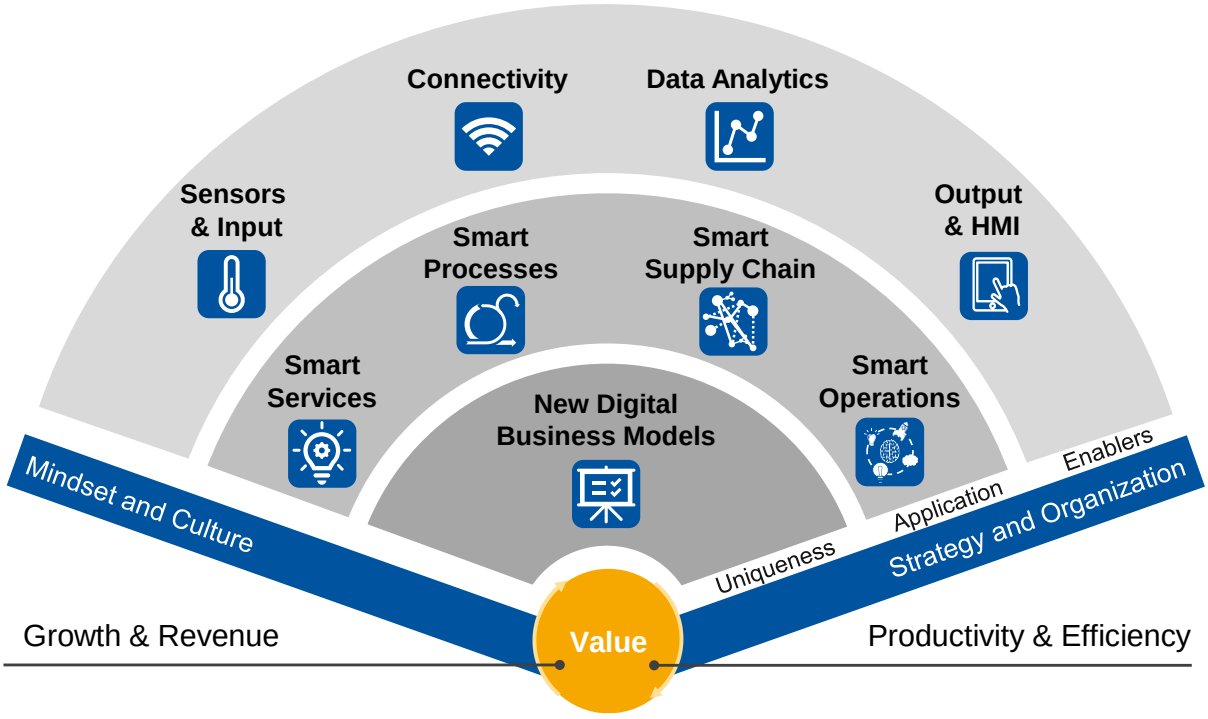

Figure 2: Logistics 4.0 Navigator

In the center of the navigator stands value creation, as all activities of a company should be primarily aimed at creating value in some form. From the perspective of a company, value can be either generated in the form of growth and revenue or by reducing costs through enhanced productivity and

efficiency. For a successful business it is of utmost importance which value it creates for the customer. This value determines how successful a company will be in gaining and keeping satisfied customers and ultimately how successful a company will be in generating growth and revenue. To make enablers, applications and business models work together successfully with the ultimate target of value creation, a company needs a coherent "Strategy and Organization" as well as a supportive "Mindset and Culture". These aspects form the framework and internal environment for a prosperous business.

The fields of the Logistics 4.0 Navigator can be described as follows:

New Digital Business Models: The business model is the foundation of a company and determines whether it will be successful and grow. Industry 4.0 enables the creation of innovative digital business models that are based on data, developed and improved with the help of data, and provided digitally to the customer.

Smart Services: The comprehensive collection of product and user data enables the offering of smart and value-added services according to the customers' needs and behaviour. In logistics, this can for example refer to monitoring of goods condition (e.g., temperature, force) and location or flexible routing and shipping according to the customers preferences.

Smart Processes: The integration of entities and goods along the full supply chain enables a seamless data exchange between systems, goods and involved stakeholders. In logistics, cloud-based IoT solutions and the continuous collection of goods-related data enable paperless logistics and efficient collaboration and processes.

Smart Supply Chain: Industry 4.0 technologies enable logistics systems to sense, process, self-learn, analyse and make decisions to solve problems and execute processes. The smart supply chain is connected with smart production systems and other networks to gain a holistic overview over all logistics processes, detect potential bottlenecks and enable customer-centric logistics services.

Smart Operations: Connectivity and seamless data exchange also creates increased transparency inside companies. Internal departments and processes, such as warehousing and intra-logistics, can be managed and monitored better to provide reliable information, e.g., current stock levels or production delays quickly and as needed to internal and external stakeholders.

Sensors & Input: The application of sensors and acquisition of data from various IT systems enables the creation of a comprehensive digital picture of the real world. This creates transparency across logistics processes in the full supply chain and enables stakeholders to see what is happening. Sensors are becoming smaller, cheaper, and more versatile. They can measure more data in increasingly difficult to reach areas and interact with each other.

Connectivity: The connection of all elements in the value network through horizontal integration of the supply chain, vertical integration of enterprise systems, and the integration of the product life cycle from development to customer utilization are the backbone of Industry 4.0 and Logistics 4.0. Extensive networks can be established ad-hoc and automatic and allow access to data in the full supply chain.

Data Analytics: Capabilities to analyse data bring intelligence to the whole value chain and enable stakeholders to understand why something is happening, predict future events like supply bottlenecks and facilitate autonomous optimization like rerouting and replanning. Modern information and communication technology (ICT) supports the storage of data in the cloud and provides resources for high-speed computing as well as artificial intelligence (AI) applications.

Output & HMI: Besides machine-controlled processes, the provision of information to the user is a central topic in Logistics 4.0. Assistance systems like smartphones, tablets and other wearables facilitate the visualization of data for the user and provide user-specific and contextualized information. This can for example be used to inform transport operators about potential delays in the production of their customers or help a warehouse operator to quickly find and identify SKUs.

C. Hong Kong Logistics 4.0 Maturity Model

To better structure the transformation towards Logistics 4.0 in a stepwise approach, the Hong Kong Logistics 4.0 Maturity Model was developed and adapted to the situation and requirements of Hong Kong SMEs. The stages and logic behind the model are derived from the Acatech Industrie 4.0 Maturity Index developed by German academic research organizations.

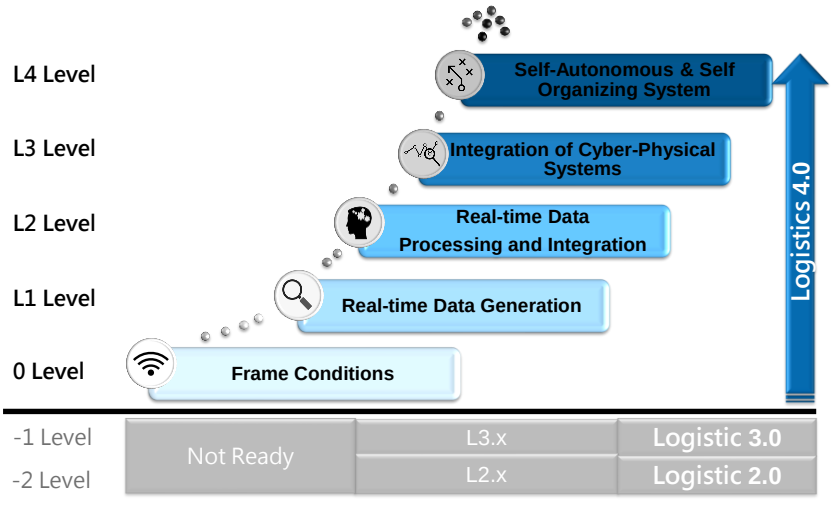

Figure 3:Maturity Levels

Every stage of the evolution towards Logistics 4.0 constitutes added value for companies and generates a competitive advantage. To ensure a sustainable development of capabilities, the transformation should be carried out successively and evenly across all departments and not in a quantum leap. In general, it should be noted that solutions up to level two are currently available, economically viable and thus suitable for industrial practice. Solutions from levels 3 and 4 are still partly under development and moreover dependent on high computing power, a high-performance IT

infrastructure and the availability and quality of big data from various sources and are therefore only suitable for application and economically viable for technologically advanced companies.

Logistics 2.0: Non-digital (Level -2)

Predominantly Logistics 2.0 process, i.e., labour intensive operations and manual information flow. Operations are highly manual and paper-based and proceed in an ad-hoc and chaotic rather than systematic manner:

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

Logistics 3.0: Systemization and Computerization (Level -1)

Predominantly Logistics 3.0 processes. Basic digitization and introduction of standalone IT systems for automation of single processes/tasks (e.g., e-mail & Fax) as well as basic 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)

Logistics 4.0: Connectivity – Foundation Condition (Level 0)

Organizational and infrastructural enablers for the implementation of Logistics 4.0. Connection of internal IT systems without media breaks regarding the flow of information in the direction of the process:

- Logistics 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

Logistics 4.0: Visibility – "What is happening?" (Level L1)

Generation and availability of data and information of all activities in real time. Seamless information flow in all directions between internal and external information sources and IT systems, creating a "single source of truth" and transparency across all processes and activities:

- Vertical integration of advanced digital tools (e.g., DMS, SCM, PMS, WMS)
- Transport management, Fleet management, Track and Trace, APS, Route/Tour planning
- Well established "Single Source of Truth"
- Real time end-to-end operation status visualization
- Use of data for basic operation analysis (descriptive)

Logistics 4.0: Transparency – "Why does it happen?" (Level L2)

Development of knowledge and insights through the analysis and aggregation of all available information and data sources. Full aggregation of internal and external real-time data to identify cause-and-effect relationships 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

Logistics 4.0: Predictability – "What will happen?" (Level L3)

Predictive analytics and human-system / system-system collaboration for decentralized decision-making. Application of simulation models, which are built on the basis of real historical data and continuously improved, in order to predict the expected resulting scenarios for certain events or decisions:

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

Logistics 4.0: Adaptability – "How can an autonomous reaction succeed?" (Level L4)

Self-optimizing processes and autonomous control of processes along the value chain. Addition of an automatic and autonomous evaluation function that can make a statement about which event or decision will lead to the best scenario to maximize the value for the company and for customers:

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

6 Key Insights for the Manufacturing and Trading Industry

A. Current digital planning and tracking tools do not yet suffice for creating planning transparency for manufacturers.

Currently available solutions that companies use for digital integrated planning as well as tracking and tracing tools are very good at creating transparency in overall value streams, but not yet sufficient for accurate planning.

21% of the surveyed companies stated that one of their major pain points is a lack of tools for planning and operation along the supply chain.

Those who have implemented advanced planning solutions that are on the market still remark that there is space for improvement. This is often due to the fact that companies want to forecast events that cannot be forecasted such as sudden disruptions of the supply chain like the global pandemic or a blockage of the Suez Canal. Existing solutions don't create the kind of transparency that companies need to perform efficient and reliable planning. Even if companies managed to create full internal transparency, there are media breaks somewhere in the chain of logistics providers where interfaces are manual and, e.g., Excels have to be sent via e-mail.

35% of surveyed companies stated that they perform manual and paper-based planning, while 59% perform manual planning with software systems, especially using Excel file. Of those using software solutions, only 14% are able to support planning based on electronically updated real-time data.

B. Digital customer interaction, scheduling and goods tracking reduce handling time.

Similar to logistics providers, manufacturers and traders benefit from digital interaction with customers, integration of customer data as well as the application of scheduling and goods tracking systems which enable companies to anticipate when an action is needed and at the same time ensure that the relevant resources, e.g., workers or transport devices are available and scheduled.

29% of surveyed companies suffer from high handling time in logistics processes.

The tracking of goods enables a more accurate prioritization and scheduling of activities to reduce handling time and allocate resources efficiently. Furthermore, companies can provide customers with information on goods location, e.g., via individual access on online platforms or automatic e-mails and thus tap new revenue streams through value-added services. However, many still lack sufficient tracking capabilities and perform the process manually.

51% of companies manually track goods with software, i.e. the location of goods is communicated via mail or phone and manually inserted in an IT system. 29% of the surveyed companies perform this process paper-based. Only 10% receive automatic updates on goods location at certain times and 8% have real-time access to goods location.

Observations from the assessments

Challenge: One visited company that provides printing products for the retail sector faced the challenge of irregular unexpected peaks in demand for retail label printing from customers. The company didn't have reliable forecasting capabilities and had to respond quickly, which caused high effort and often resulted in bottlenecks and longer handling times.

Solution: A potential solution for this challenge would be a direct integration to customers, collection of customer data and the setup of efficient information channels for direct interaction with customers to receive requests of as quickly as possible to enhance planning and forecasting capabilities and schedule production accordingly.

C. Vehicle tracking and delivery scheduling help improve transparency.

Transparency of logistics processes can be increased by tracking delivery vehicles and applying software to schedule delivery.

37% of the surveyed companies schedule deliveries manually and paper-based, while 53% do it manually supported by software systems. Only 8% have capabilities to electronically update their delivery schedule in real-time.

Many companies do not yet implement corresponding systems because of restraints coming from employees or external contractors, who are not convinced of these digital solutions. Nevertheless, vehicle tracking, e.g., via a transport management system (TMS) and delivery scheduling systems make operations more efficient and stable for all involved stakeholders. It is therefore recommended to educate people about the benefits of such solutions for their daily operations and promote a digital culture to increase acceptance.

25% of surveyed companies perform no tracking of vehicles, while 19% do it manually via phone calls and another 35% support this process with software. Only 15% get electronic updates on the location of vehicles at certain times.

7 Roadmap for Manufacturing and Trading Industry

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

Figure 4: Roadmap for Manufacturing and Trading Industry

8 Logistics 4.0 Use Cases and Applications

Further detailing the benefits of each pilot project in the roadmap and describing the specific use case or application

Level -2 to -1: The first step is the transformation from no digitization, highly manual and paper-based operations and an ad-hoc and chaotic rather than systematic manner into predominantly logistics 3.0 processes.

-2 to -1	**Define service offerings and define revenue streams**	1 2
Data-driven business model	Define the services and products that can be offered to the customers and define how revenue is generated from the core business activities. Define the deliverable value, develop a general pricing strategy and scope of the service. This is a crucial step to prepare future business strategies and find new revenue streams.	
-2 to -1	**Define standards for provision of services**	1 2
Smart services	Define how to provide the customer the with the promised value through the services. Define the possible order methods for different types of products to determine how the product manufactured to the customer needs. Having a clear outline will drive customer satisfaction.	
-2 to -1	**Establish an information channel for customer communication**	1 2
Smart services	Develop standard communication emails or fax to directly provide customers with information, e.g., on the status of the material and the finished parts, expected delivery date and other relatable details. Define internal code of conduct for communicating with the customers.	
-2 to -1	**Define standards for overarching processes and support them digitally**	1 2
Smart processes	Standardize the functions of the business departments like human resource management, sales and marketing, finance and accounting, for coordinating with the operational departments (e.g., define standard recruiting and onboarding process) and create digital standard templates to support their activities (e.g., excel template for RFQs).	
-2 to -1	**Define standards for interaction with suppliers, customers and partners**	1 2
Smart supply chain	Develop supply chain interaction by ensuring access to information in a standardized format for customers and suppliers and coupling organization processes with the partners in the supply chain (e.g., standards to make an order, a standard process for selection of suppliers).	
-2 to -1	**Define the operational procedure for internal processes**	1 2
Smart operations	Clearly define the operational procedure for internal logistics processes from receival to dispatch. Streamline the operations by defining the standard flow of product through the warehouse (e.g., define process flow diagrams in excel). Document the steps of the tasks and the sequence in which they should be performed and the responsible employee who should do it. This raises a sense of responsibility amongst the workforce.	

-2 to -1	**Standardized digital templates for storing and tracking information** 1 2
Smart operations	Clearly define the operational procedure for internal logistics processes from receival to dispatch. Streamline the operations by defining the standard flow of product through the warehouse (e.g., define process flow diagrams in excel). Document the steps of the tasks and the sequence in which they should be performed and the responsible employee who should do it. This raises a sense of responsibility amongst the workforce.
-2 to -1	**Implement computer applications and digital interfaces for process execution** 1 2
Smart technologies	Start the use of digital technologies by using computer applications for executing all departmental functions and systematically recording the data (e.g., filling handwritten forms substituted by digital forms). Conduct cross-department information transfer via e-mails. This increases the productivity of the process by virtually reducing the time and distance spent on performing tasks manually.
-2 to -1	**Set up basic IT governance** 1 2
Strategy & organization	Enable effective and efficient use of IT in the organization by setting up a basic IT governance system. Define IT goals and align the organization's business goals with them to support computerization. By following a formal framework, organizations can produce measurable results by taking stakeholders' interests into account.
-2 to -1	**Define a vision & goals** 1 2
Strategy & organization	Define a vision for how digital applications can improve service, cost, agility, and inventory levels and consistently implement process and organizational changes that use these technologies to drive operational excellence.
-2 to -1	**Implement ISO 9001 Standards** 1 2
Strategy & organization	The process approach promoted by ISO 9001 systematically identifies processes that are part of your quality system and identifies the interactions between them and may be applied on all processes. This concept follows the Plan, Do, Check, Act cycle for implementing change which, when followed and repeated, would lead to repeated improvements in the process it was applied to.
-2 to -1	**Create awareness for the need and adherence to processes** 1 2
Culture & mindset	The corporate culture, as a totality of action patterns as well as convictions that are accepted as binding in a company, represents the basis for the way of cooperation. In order to gain commitment, it is therefore important to create awareness of the necessity of the processes and trust in them.
-2 to -1	**Establish process guides and guidelines** 1 2
Culture & mindset	Consistent implementation of the guiding principles leads to improved efficiency in the processes. A process map as a guideline can help to track and further refine the processes.

Level -1 to 0: Basic digitization and introduction of standalone IT systems for automation of single processes or tasks are implemented and basic processes' systemization are done. The next stage with connections to internal IT systems without media breaks can be achieved by the following steps.

-1 to 0	**Develop a business model & offer services to customer digitally** 1 2
Data-driven business model	Develop a business model by identifying your key customers and establish a strong value proposition through your products and services. Customers should be able to access the offerings through digital platforms (e.g., the company website).
-1 to 0	**Provide guaranteed product & order related information from Sales to customers on demand via E-Mail (e.g., delivery time)** 1 2
Smart services	Customer service representatives must have access to the information on the status of the customer order to provide guaranteed information regarding the status of the order. Regular emails to the customer to provide order related information improve customer relations.
-1 to 0	**Implement IT systems to support processes (e.g., CRM, OMS)** 1 2
Smart processes	For the execution of defined tasks, implement the required IT systems (e.g., Customer relationship management solution, Order management system) by considering the functional requirements. Along with cost, it is also important to take into account the factors like scalability, usability, integration with other systems.
-1 to 0	**Set up knowledge management system** 1 2
Smart processes	A knowledge management tool helps in organizing information and documentation that can be accessed by everyone in the organization. Implement an organization wide IT system to store process know how and create knowledge base to improve understanding and promote collaboration between the departments.
-1 to 0	**Implement IT system for managing information in value chain** 1 2
Smart supply chain	Engage with the stakeholders in the value chain through digital interfaces by implementing IT systems. Evaluate and manage supply chain partners by implementing supplier relationship management tool to improve operational efficiency. Develop a logistics platform (TMS system) to plan and execute the process and store related documents.
-1 to 0	**Implement WMS system to digitize paper-based processes** 1 2
Smart operations	Warehouse Management Systems provide visibility in handling warehousing functions. Implement a WMS system to track goods and material movement through the warehouse, track inventory levels, manage order fulfilment processes.

-1 to 0	**Inventory levels and locations tracking through WMS system** 1 2
Smart operations	Tracking SKUs in possession and their storage locations to create visibility on the inventory by using a barcode system for identification of the material in the warehouses and distribution centres.
-1 to 0	**Implement basic MES for the management of material flow/intralogistics** 1 2
Smart operations	A manufacturing execution system, or MES, is a comprehensive, dynamic software system that monitors, tracks, documents, and controls the process of manufacturing goods from raw materials to finished products. The main objective of an MES is to ensure the effective execution of manufacturing operations and to improve production performance.
-1 to 0	**Implement domain-specific application software (e.g., ERP)** 1 2
Smart technologies	Implement domain-specific application software (e.g., ERP, SRM) and eliminate the need of e-mails and telephone calls to exchange information between departments.
-1 to 0	**Set up basic IT Infrastructure** 1 2
Smart technologies	For the introduction of digital technologies and IT systems, an IT infrastructure must be developed to operate and manage the physical and network components of an enterprise IT landscape.
-1 to 0	**Establish Lean approach starting with 5S methodology** 1 2
Strategy & organization	Follow lean methodology approach for optimization of available resources in the organization to create value for the customer. Create sustainable processes starting with 5S to eliminate waste and standardize working habits. Map value stream to recognize the wastes and implement Kanban pull principle to increase throughput.
-1 to 0	**Start with formalization of department / process specific knowledge** 1 2
Culture & mindset	Typically, “knowledge” is already available in different representations ranging from technical documents, construction plans, sheets and experiences of human experts. Knowledge Formalization is the process of translating narrative guidelines into structured knowledge.

Level 0 to L1: The next level to be reached offers a seamless, real-time information flow in all directions between internal and external information sources and IT systems. Creating a "single source of truth" and more transparency across all processes and activities is a main task in this level.

0 to L1	**Implement tracking & market analysis tools**	1 2
Data-driven business model	Implement tracking tools and market analysis tools to analyze the performance of the business model. These tools can be used to make adjustments later more efficiently.	
0 to L1	**Enable customers to interact with services at any time**	1 2
Data-driven business model	Set up dedicated channels (e.g., personal login on website, e-mails, chatbots) to provide customers directly with information on the status of their order such as the shipment, expected delivery date and other relatable details 24/7 and in real-time (low information latency). Define internal code of conduct for communicating with the customers.	
0 to L1	**Create digital interface for manual service selection**	1 2
Smart services	Create a digital interface for customers (e.g., online platform with login) for permanent access to product- and order-related information (e.g., status, expected arrival) and manually select additional services.	
0 to L1	**Automatic notifications for customers / alerting functions**	1 2
Smart services	Notifications are sent automatically e.g., by e-mail, in the event of material bottlenecks, delivery delays, etc.	
0 to L1	**Implement management dashboards with real-time KPIs**	1 2
Smart processes	To visualize relevant processes with real-time KPIs a management dashboard should be implemented. This allows you to keep an overview and have the KPIs relevant for decision-making sorted at a glance.	
0 to L1	**Formalize knowledge management supported by simple IT tools**	1 2
Smart processes	Formalize knowledge management (e.g., action sheets for improvement actions, learnings from specific situations) in a process and support this with simple IT tools e.g., WIKI Sharepoint.	
0 to L1	**Generate coaching and mentoring structures**	1 2
Smart processes	Coaching and mentoring structures are created to preserve and formalize the experience of senior employees. This prevents the loss of information and makes you more independent of the knowledge of particular employees.	

0 to L1	**Get information automatically from logistics providers**	1 2
Smart supply chain	Automatic provision of information from the transport or logistics provider, such as status of material flow, delays, etc. This sets the basis for making decisions regarding production, e.g. if the production line should change or shift the planned schedule or use different materials.	
0 to L1	**Digital IT system integration of providers (EDIs/APIs)**	1 2
Smart supply chain	The first digital integration with IT systems of providers can be set up using EDIs or APIs. This enables real-time information exchange in the supply chain.	
0 to L1	**Advanced planning and scheduling**	1 2
Smart supply chain	Coordinate material, resource, logistics and production planning activities by implementing APS to consolidate shipments, dynamically sequence material flow, production steps as well as pickup and delivery locations based on the current setting and minimize lead time.	
0 to L1	**Implementation of a dynamic milkrun**	1 2
Smart operations	In an inhouse milkrun, the goods are usually transported from one source (supermarket) to various sinks (e.g., production lines). It enables demand-driven material supply of working stations in facilities through the digitization of material flow. In addition, production and assembly lines can be linked in such a way that an automatic supply circuit is created via the internal material flow, thus reducing manual replenishment movements.	
0 to L1	**Prepare digital lean data collection with digital resources**	1 2
Smart operations	To realize its full potential, digital lean requires an integrated IT/OT infrastructure that aligns control systems, industrial networks and connected machines with cloud computing, mobile computing, data analytics and AI algorithms. Production processes generate data that serves as input for all improvement measures.	
0 to L1	**Enhance track & trace capabilities**	1 2
Smart operations	The need for track and trace capabilities in manufacturing is the threat of contamination or recalls impacts safety, and the responses to those events are highly regulated. Enhanced track and trace capabilities support advanced analytics for reporting requirements, such as in the event of a recall, and provide the real-time intelligence that can drive better inventory forecasting and more strategic operational decisions. Therefore, the application of IoT devices is helpful and should be implemented, such as a scanner & barcode system.	
0 to L1	**Deploy alerting functions to specific situations**	1 2
Smart operations	Use alerting functions for specific situations related to internal processes and material flows, such as shortages in the warehouse. Bottlenecks can be avoided with automatic detection of restocking levels, minimum stock level notification, and continuous monitoring of stock levels.	

0 to L1	**Software to establish domain-specific single source of truth architecture**	1 2
Smart technologies	Integrate domain-specific application software to establish a single source of truth architecture. With integration, only one system is needed for example for resource planning, and there are no more system discontinuities.	
0 to L1	**Infrastructure for collecting times, levels, material flow**	1 2
Smart technologies	Sensors increase the level of automated collection and processing of data and broaden management visibility across the supply chain to help companies reduce operating costs and improve asset efficiency. Processes like inventory counting and material sorting can become more automated with the assistance of a sensor infrastructure, thus helping to improve the productivity.	
0 to L1	**Definition of a digital strategy aligned with company goals**	1 2
Strategy & organization	Defining a strategy is an essential part of the transformation process to ensure that technology is deployed in a way that supports your business goals and can be divided into digital objectives.	
0 to L1	**Set up interdisciplinary team for Industry 4.0 projects**	1 2
Strategy & organization	Interdisciplinary teams should be established to implement and steer Industry 4.0 projects e.g., for the implementation of IoT applications.	
0 to L1	**Set up teams focusing on the improvement of specific KPIs**	1 2
Strategy & organization	Besides the Industry 4.0 project teams it is also important to set up cross-department teams (business teams), that focus on the improvement of specific KPIs with digital tools (e.g., lead time, inventory levels, on-time delivery) in order to ensure the continuous improvement process.	
0 to L1	**Knowledge transfer between departments**	1 2
Culture & mindset	Knowledge Transfer is a method of sharing information, abilities, and ideas across different areas in your business. Knowledge transfer systems aid you in streamlining your knowledge which ensures that everyone in the company has the information they need.	
0 to L1	**Promote acceptance and usage of data and IT systems**	1 2
Culture & mindset	Companies able to take advantage of the information coming from the use of data will have a competitive advantage by being able to make decisions based on greater knowledge of customers and competition. But the acceptance for using the data has to be given. A higher level of acceptance of data and IT systems promotes the implementation.	

0 to L1	**Promote open communication & create learning atmosphere**	1 2
Culture & mindset	Open and honest communication in the workplace is a non-negotiable for high-performing teams. Without open communication, tasks can go uncompleted, team members can become disengaged, and company culture can get lost. Additionally, developing a culture that supports learning is an investment, but it provides tremendous benefits for your organization. A learning culture is important because it helps you capitalize on your employees' potential and grow your business.	

Level L1 to L2: With the transformation from level L1 to L2 the goal is to achieve a full aggregation of internal and external real-time data to identify cause-and-effect relationships between events and their root cause.

L1 to L2	**Use data analytics to improve services and business model**	1 2
Data-driven business model	Using data analytics and transforming the business models in parallel will create new opportunities for revenue streams, customers, products and services.	

L1 to L2	**Initiation of the production process by the customer**	1 2
Data-driven business model	Allowing the customer to log in and initiate the production process digitally. Each order triggers the company's semi-autonomous production system, which independently determines the priority of each order and automatically assigns it to the right machine with open capacity, under the surveillance of the plant employees.	

L1 to L2	**Installation of a real-time data query in the online platform**	1 2
Smart services	The analyzed data can be requested by the customer in real time and relevant options can be suggested to the customer.	

L1 to L2	**Chatbot to address customer requests and concerns**	1 2
Smart services	When a customer faces an issue with delivery, a virtual assistant acts like a human agent and helps customers by answering all of their concerns, questions and providing relevant information on the product bought. The chatbot is also able to give recommendations and solutions to the customer of what to do next and how to solve his/her issue. The data of the chatbot can be used to understand trends and drive root cause analysis.	

L1 to L2	**Automated outlier detection and root cause analysis**	1 2
Smart processes	Automated outlier detection compares current behavior with what it considers reasonable, and if it sees a significant deviation, it will flag the component as a potential root cause. Automated root cause analysis uses automated outlier or anomaly detection to decide if a component can be a root cause of a problem.	

L1 to L2	**Customer journey analytics**	1 2
Smart processes	Customer Journey Analytics delivers the evidence-based analytics needed for reliable insights into actual customer experience when dealing with your digital channels. This can be used to shape winning customer engagement strategies and for investing where you get the greatest differentiation and return.	

L1 to L2	**Establish first digital twin structure**	1 2
Smart supply chain	Digital twins are extensions of an environment, not the static replicas. At first address the size and scope of the digital twin, then choose the most suitable information type e.g., tracking equipment. Finally, you need software that powers the digital twin and add details and data processing functionalities.	

L1 to L2	**Get real-time performance & material buffers tracking**	1 2
Smart supply chain	Sensors report locations and enable condition monitoring of sensitive goods during production or transport along the supply chain. Thanks to digital technologies, the boundaries between manufacturer and service provider are blurring, which improves customer satisfaction as well as throughput time and product quality.	

L1 to L2	**Automation of the inventory status check and real-time optimization parameters suggested by the system**	1 2
Smart operations	Automatized check of the inventory status through wireless traceability of the inventory, items can be easily located and full visibility on item level can be achieved. This offers real-time optimization parameters and suggestions (inventory optimization).	

L1 to L2	**Implementation of a data-driven material supply of working stations**	1 2
Smart operations	The implementation of a data-driven material supply of working stations in facilities through the digitization of material flow and the networking of machines and IT systems (e.g., Dynamic milkrun) enables a more efficient production.	

L1 to L2	**Introducing automated cobots, conveyors and AGVs for the production line**	1 2
Smart operations	Introducing automated cobots or conveyors or AGVs for part or material handling and transportation. Processes are still controlled through setpoints and commands from a central controller. Machine learning is used to optimize the control parameters of machines and lines.	

L1 to L2	**Developing IT landscape and single source of truth**	1 2
Smart technologies	A single source of truth (SSOT) is the practice of aggregating the data from many systems within an organization to a single location. A SSOT is not a system, tool, or strategy, but rather a state of being for a company's data in that it can all be found via a single reference point.	

L1 to L2	**Set up cloud and edge computing to process real-time data**	1 2
Smart technologies	Cloud or edge computing solutions add data processing capability to the automation environment. Data can thus be stored and processed locally on the shop floor without long transmission paths. Cloud and edge computing offers a device-, platform- and location-independent access to the data.	
L1 to L2	**Implement data governance organization**	1 2
Strategy & organizaiton	Data governance refers to the organizational policies and procedures that govern data management. Data governance guarantees that data is safe and secure. It also ensures that the data provided is protected, reliable, documented and controlled. Evaluated data governance is also a practice that needs to be cultivated and kept alive. It is about having a common and shared understanding of it, and efficiently and effectively managing it in order to optimize business value.	
L1 to L2	**Set up continuous improvement teams (KAIZEN)**	1 2
Strategy & oganization	The continuous improvement team is actively engaged in defining and implementing projects while managing the overall process. They are immersed in every aspect of the process and may be an active leader or participant in a project.	
L1 to L2	**Develop qualification of employees to handle and process data**	1 2
Strategy & oganization	During the maturity change process, various job positions will disappear and some will be newly created. The main reason for retraining existing employees is their knowledge of the current manufacturing process. In the last two levels, however, there will be a need for educated and skilled workers in the field of computing, self-learning algorithms and data analysis.	
L1 to L2	**Promote agile working culture**	1 2
Culture & mindset	An important part of an agile work culture is increasing flexibility in many forms. It is an effective way of working in a project that promotes collaboration on all levels with a common goal. Culturally and mentally, employees have to be flexible to think about out-of-the-box solutions, adapt to changing needs, dive into new topics and cooperate with employees outside of their normal department, leaving their comfort zone.	
L1 to L2	**Establish culture of data-driven decision making**	1 2
Culture & mindset	The aim is to build a culture that encourages all employees of the company to collaborate to keep data at the center of decision-making, from the data owner to the data scientist, to the business analyst, and finally to every employee who uses data in their department. Data-driven culture is enabled by access to data, management of data quality, methodological knowledge for analyzing data, and technologies that enable them to be prepared and analyzed.	

Level L2 to L3: The transformation to level L3 needs predictive analytics and human-system and system-system collaboration for decentralized decision-making.

L2 to L3	**Services and business model adjustments suggested by system**	1 2
Data-driven business model	New Services and business models are developed or adjusted by the system using data from market analysis and historical data in collaboration with customers. Possible options are presented and can be selected by the management.	
L2 to L3	**Offer customization of specific services**	1 2
Data-driven business model	In today's environment, however, customers have needs that are hard to predict and often change in unanticipated ways. Providing customers with the flexibility of managing orders and make changes in an ongoing production process if desired e.g., change of color or adding extra features.	
L2 to L3	**Contextual service across every channel**	1 2
Smart services	Leverage customer data for seamless, personalized and contextual service across every channel. Aggregated data from a variety of channels and sources e.g., email, e-commerce, device data, and more are taken to deliver associated and personalized services. By that the customer can simply choose between relevant recommended offers and information.	
L2 to L3	**Supply chain risk identification/management**	1 2
Smart services	Identification, assessment & management of risks in supply chains taking into account internal and external data like economic and political events. This helps to proactively identify, analyze and mitigate all types of supply chain risks. It provides the opportunity to turn risk into competitive advantage, for example, by offering revenue maximizing alternatives through the system.	
L2 to L3	**Digital supply chain twin**	1 2
Smart supply chain	A Digital Supply Chain Twin is a digital representation of the relationships between all physical units of the end-to-end supply chain processes - products, customers, markets, distribution centers/warehouses, plants, finance, attributes etc. They are closely linked to their real counterparts. They are used to understand the situation or state of the system in order to optimize operations and respond efficiently to changes. By integrating advanced analytics, simulation and optimization functionalities, the performance and resilience of the supply chain can be further enhanced.	

L2 to L3	**Model and detect unexpected conditions and give solutions for material flow and inventory optimization**	1 2
Smart supply chain	Organizations can better prepare for short-term behavioral changes that affect the supply chain and logistics such as news, weather, shortages, and manufacturing promotions. By utilizing predictive analytics models to detect unexpected conditions, they can better adjust shipments and inventory in response to specific, time-sensitive changes in routes or inventory.	
L2 to L3	**Autonomous mobile robots (AMR)**	1 2
Smart operations	Compared to an automated guided vehicle (AGV) system in which a central unit takes control of scheduling, routing, and dispatching decisions for all AGVs, Autonomous mobile robots (AMRs) can communicate and negotiate independently with other resources like machines and systems and thus decentralize the decision-making process. Decentralized decision-making allows the system to react dynamically to changes in the system state and environment.	
L2 to L3	**Dynamic forward simulation with suggested action plan**	1 2
Smart operations	By linking horizontal and vertical supply chain simulation tools, the two areas are brought together to enable end to end supply chain simulation. The results of the horizontal tool in the form of a rough planning are transferred by a scheduling engine into a detailed planning. This order sequence is checked for feasibility by the vertical supply chain tool and is fed back to the horizontal tool. This process is repeated iteratively until the best possible planning results are found.	
L2 to L3	Self-organizing, intelligent inventory	1 2
Smart operations	AI-powered demand forecasting and bespoke algorithms, tailored to a business' needs, to better manage inventory levels and allocate stock across the network. It also strongly influences how much manufacturers plan to make, providing an indication of exactly how much they need and where they need it. With a focus on ensuring cost-effective resilience, applying data-driven decision making leads to increased service and profitability, less waste and a reduced carbon footprint.	
L2 to L3	Implementation of 5G network	1 2
Smart technologies	5G is a new mobile communications standard designed to enable fast, mobile Internet access. 5G's performance and reliability aspects are relevant in terms of indoor logistics for the control of driverless transport systems. It enables the user to coordinate entire AGV fleets in a confined space and to manage the control and route data in a company's Edge Cloud. Other possible applications include robotics, collaboration between machines and humans as well as imaging techniques.	
L2 to L3	Embed cybersecurity system	1 2
Strategy & organization	Cybersecurity inherently becomes something requiring management through innovative and technical approaches to protect enterprise infrastructure and business applications. Introduce a scalable solution that protects devices and sensors as well as communication and data exchange without compromising performance.	

9 Self-Assessment Manual

A self-assessment tool was developed together with the cross-industry roadmaps. The tool helps companies to independently assess their own Logistics 4.0 maturity level. For this purpose, a collection of questions in various dimensions is provided, which are derived from the Logistics 4.0 Navigator. After answering all the questions, companies receive an individual assessment score. This score can be used to quantitatively depict the status quo of developments with regard to Logistics 4.0 and enables the company to position itself in the cross-industry roadmap. This enables the selection of suitable use cases and actions from the roadmap in the next step for a stepwise transformation to Logistics 4.0.

A. 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 Logistics 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.

B. Application of the Self-Assessment Tool

To use the self-assessment tool, users must answer questions 1-20. To do this, the answer that applies to the company must be chosen by selecting the suitable columns and the corresponding score must be selected in the orange field in column J (see picture).

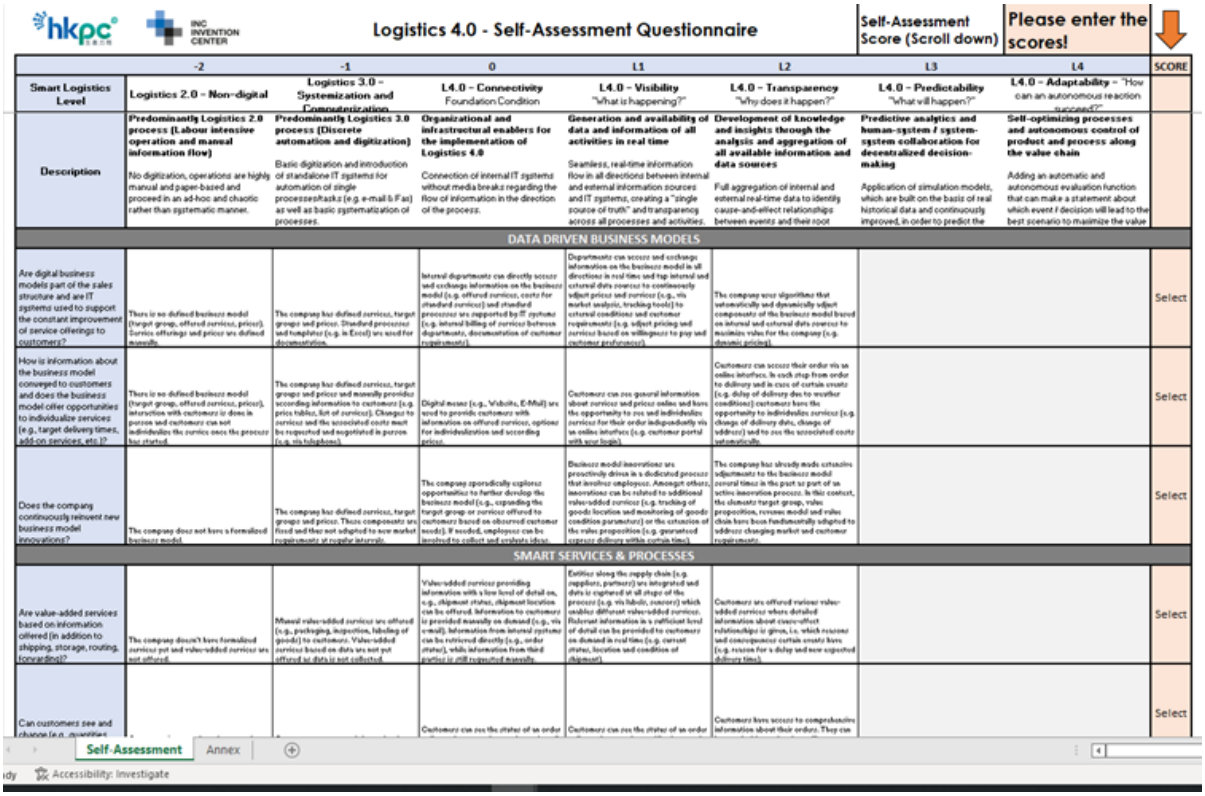

Figure 5: Self-Assessment Tool

The score ranges from -2 to a score between L1 and L4 depending on the maximum maturity to be achieved in the respective question. Some questions only go up to level L1 "Visibility", because a higher score is not possible or irrelevant for the respective question. The total score is calculated automatically and can be found in field L1 after all questions have been answered. The total score equals the lowest score across all dimensions, as in the context of digitalization the weakest link defines the system and should thus serve as a starting point to implement use cases and equally progress throughout all areas and departments of a company. Finally, the result can be used to identify the next steps and value-adding use cases for the transformation to Logistics 4.0 in conjunction with the according roadmap for the shipping or the manufacturing and trading industry.