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Recommendation

ITU-T Y.4910 (03/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet of things and smart cities and communities – Evaluation and assessment

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Maturity model of digital supply chain for smart sustainable cities

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Recommendation ITU-T Y.4910

Maturity model of digital supply chain for smart sustainable cities

Summary

With the rapid development of advanced information technologies such as the Internet of things (IoT), big data and cloud computing, the traditional supply chain has been transformed into a digital supply chain. Digital supply chains may help to maintain high growth by reducing operation costs and improving the efficiency of supply chain management with the help of digital methods. As a result, digital supply chains can assist with the construction and management of smart sustainable cities (SSC).

Recommendation ITU-T Y.4910 provides a maturity model of digital supply chain for SSC referring to the key performance indicators (KPIs) for SSCs in Recommendation ITU-T Y.4900 and the maturity model for SSC in Recommendation ITU-T Y.4904. Both of these Recommendations support the maturity model for digital supply chains. The use of the maturity model for digital supply chains has specific benefits for socioeconomic indicators, such as: environmental sustainability, productivity, innovation, and trade. This maturity model helps identify the goals, levels, dimensions and assessment methods of digital supply chain for SSC. It is designed as a practical tool for city managers and all related stakeholders to study the performance and benefits of digital supply chain from economic, social and environmental perspectives. Thus, this Recommendation gives general guidance for accurately assessing the maturity of digital supply chains and help in achieving sustainable development goals for SSC.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Keywords

Digital supply chain, key performance indicators (KPIs), maturity model, smart sustainable city (SSC).

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Maturity model of digital supply chain for smart sustainable cities

1 Scope

This Recommendation presents a maturity model, which contains maturity levels and maturity dimensions, as well as maturity guidelines and assessment methods of the digital supply chain for smart sustainable cities (SSC). The goal of this Recommendation is to provide an effective way to achieve sustainable development goals for SSC by assessing and promoting the use of advanced technologies, and gradually improving the capabilities of digital supply chain.

The scope of this Recommendation includes:

1) Maturity model of digital supply chain for SSC;
2) Maturity levels of digital supply chain for SSC;
3) Maturity dimensions of digital supply chain for SSC; and
4) Maturity assessment methods of digital supply chain for SSC.

This Recommendation is not intended either to compare or to prescribe any commercial products or solutions. It is intended to be a technology-neutral Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.4900] Recommendation ITU-T Y.4900/L.1600 (2016), *Overview of key performance indicators in smart sustainable cities*.

[ITU-T Y.4904] Recommendation ITU-T Y.4904 (2019), *Smart sustainable cities maturity model*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 digital supply chain: A smart, efficient, data-driven network structure, which is formed by suppliers, manufacturers, service providers, distributors and consumers and other subjects, so as to plan, organize, control and optimize the entire business process from initial raw materials to final products and services.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AGV Automated Guided Vehicle

CRM Customer Relationship Management

DSC Digital Supply Chain

ERP Enterprise Resource Planning

KPI Key Performance Indicators

R&D Research and Development

SDG Sustainable Development Goal

SRM Supplier Relationship Management

SSC Smart Sustainable City

WMS Warehouse Management System

5 Conventions

In this Recommendation:

The keywords "**is required**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keyword "**is recommended**" indicates an optional requirement which is permissible, without implying any sense of being recommended. These terms are not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Overview of the maturity model

As shown in Figure 1, the digital supply chain maturity model consists of maturity levels and maturity dimensions, which can be used to achieve the sustainable development goals for smart sustainable cities (SSC) by evaluating the maturity of the digital supply chain. Based on the maturity model of digital supply chain, relevant stakeholders can comprehensively evaluate the maturity level of digital supply chain for SSC, or select to evaluate the level and performance of several key activities of a digital supply chain for SSC.

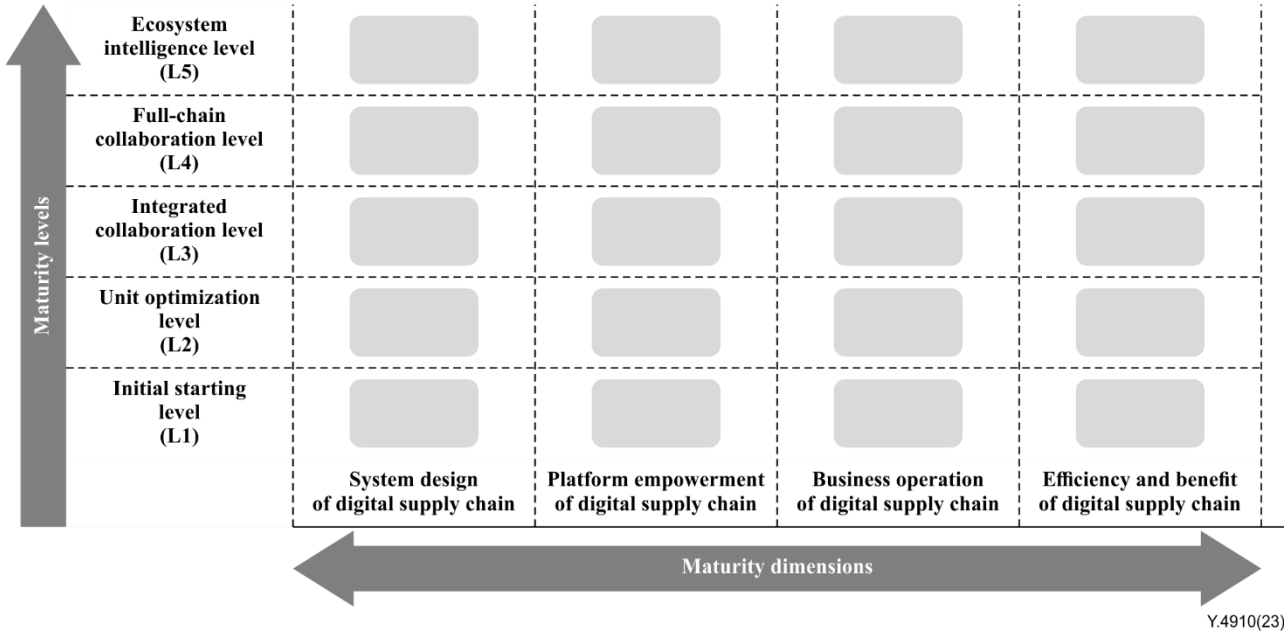

Figure 1 – Maturity model of digital supply chain

7 Maturity levels

7.1 Overview

The maturity levels of digital supply chain can be divided into initial starting level (L1), unit optimization level (L2), integrated collaboration level (L3), full-chain collaboration level (L4), and ecosystem intelligence level (L5), as shown in Figure 2. The requirements of these five levels rise gradually.

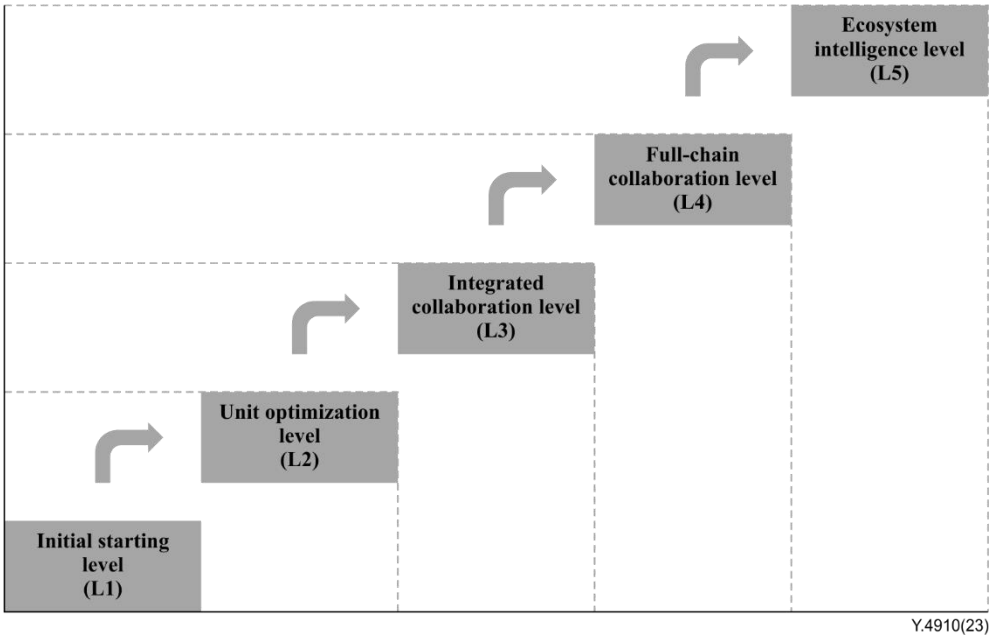

Figure 2 – Maturity levels of digital supply chain

7.2 Initial starting level (L1)

The general characteristics of the digital supply chain at the initial starting level (L1) are as follows:

- Realize the chain architecture of the supply chain of business flow, logistics, data flow and capital flow from the supplier to the consumer.
- Realize the ability to standardize the application of information technology and digital tools around business units of the supply chain.
- Realize the standardized management of key business in the supply chain, such as planning, procurement, production, delivery, and services.
- Realize the supply chain system with the smooth operation under normal conditions.

7.3 Unit optimization level (L2)

The general characteristics of the digital supply chain at the unit optimization level (L2) are as follows:

- Realize the chain architecture of the supply chain with multi-sources and single-chain business flow, logistics, data flow and capital flow from the supplier to the consumer.
- Realize the ability to effectively apply information technology, automation equipment and digital tools around key business units of the supply chain.
- Realize the ability to achieve efficient execution and transparent visibility of a single business unit in the supply chain, such as planning, procurement, production, delivery, and services.
- Realize the supply chain system with smooth operation under normal conditions and achievement of the expected value benefits.

7.4 Integrated collaboration level (L3)

The general characteristics of the digital supply chain at the integrated collaboration level (L3) are as follows:

- Realize the chain architecture of the supply chain with multi-sources and single-chain business flow, logistics, data flow and capital flow from supplier to consumer, and realize the network connection among each of the nodes of the supply chain.
- Realize the ability to deploy and apply the digital platform and automation equipment that support the integrated operation of the core business of the supply chain, and realize the end-to-end integration of the supply chain data.
- Realize the ability to carry out integrated coordination of supply chain operations such as planning, procurement, production, delivery, and services.
- Realize the supply chain system with timely risks control, continuous operation and continuous creation of value benefits.

7.5 Full-chain collaboration level (L4)

The general characteristics of the digital supply chain at the full-chain collaboration level (L4) are as follows:

- Realize the mesh supply chain architecture with the consumer as the centre and with suppliers, manufacturers, distributors, service providers and other partners in parallel with business flow, logistics, data flow and capital flow.
- Realize the ability to deploy and apply the digital platform and automation equipment that support the whole chain business coordination of the supply chain, the construction of the supply chain knowledge base and model base, and the ability of data analysis and modelling of the whole supply chain.

- Realize the ability to conduct online awareness, real-time analysis, dynamic decision-making and precise execution of business across supply chain partners.
- Realize the supply chain system with the continuous operation, flexible adjustment and the creation of adding value in an uncertain environment.

7.6 Ecosystem intelligence level (L5)

The general characteristics of the digital supply chain at the ecosystem intelligence level (L5) are as follows:

- Realize the supply chain ecosystem with consumer as the centre and establish comprehensive business, data and value connections with supply chain partners and external stakeholders.
- Realize the ability to deploy and apply the digital platform and automation equipment that support the ecosystem operation of the supply chain, the construction of the digital twin of the supply chain ecosystem, and the scene digitalization, resource modularization and business intelligence of the supply chain ecosystem.
- Realize the ability of business self-awareness, self-execution, self-learning and self-optimization among supply chain ecosystem partners.
- Realize the supply chain ecosystem with high resilience and flexibility and adaptive adjustment and continuous creation of added value in the internal and external environment.

8 Maturity dimensions of digital supply chain for SSC

8.1 Overview

Digital supply chain maturity includes four maturity dimensions, including system design of digital supply chain (D1), platform empowerment of digital supply chain (D2), business operation of digital supply chain (D3) and efficiency and benefit of digital supply chain (D4), as well as 18 maturity sub-dimensions, as shown in Table 1.

Table 1 – Maturity dimensions and sub-dimensions of digital supply chain

Maturity dimensions	Maturity sub-dimensions
System design of digital supply chain (D1)	Strategic planning of digital supply chain (D1.1)
	Organizational structure of digital supply chain (D1.2)
	Cooperation model of digital supply chain (D1.3)
	Network structure of digital supply chain (D1.4)
	Capability layout of digital supply chain (D1.5)
Platform empowerment of digital supply chain (D2)	Enabling technology of digital supply chain (D2.1)
	Data management of digital supply chain (D2.2)
	Data model of digital supply chain (D2.3)
	Information traceability of digital supply chain (D2.4)
Business operation of digital supply chain (D3)	Planning and forecasting of digital supply chain (D3.1)
	Diversified sourcing and procurement (D3.2)
	Intelligent production management (D3.3)
	Precise delivery of orders (D3.4)
	Digital customer service (D3.5)

Table 1 – Maturity dimensions and sub-dimensions of digital supply chain

Maturity dimensions	Maturity sub-dimensions
Efficiency and benefit of digital supply chain (D4)	Flexibility of digital supply chain (D4.1)
	Resilience of digital supply chain (D4.2)
	Risk prevention and control of digital supply chain (D4.3)
	Comprehensive performance of digital supply chain (D4.4)

The contents of the four maturity dimensions are as follows:

- System design of digital supply chain: Mainly assess the planning ability of top-level strategy and structural layout of digital supply chain from the aspects of 5 sub-dimensions, including strategic planning of digital supply chain (D1.1), organizational structure of digital supply chain (D1.2), cooperation mode of digital supply chain (D1.3), network structure of digital supply chain (D1.4) and capability layout of digital supply chain (D1.5).
- Platform empowerment of digital supply chain: Mainly assess the empowering effect of information technology, automatic equipment and digital platform on digital supply chain from the aspects of 4 sub-dimensions, including enabling technology of digital supply chain (D2.1), data management of digital supply chain (D2.2), data model of digital supply chain (D2.3) and information traceability of digital supply chain (D2.4).
- Business operation of digital supply chain: Mainly assess the digital level of supply chain planning, procurement, production, delivery, service and other business activities from the aspects of 5 sub-dimensions, including planning and forecasting of digital supply chain (D3.1), diversified sourcing and procurement (D3.2), intelligent production management (D3.3), precise delivery of orders (D3.4) and digital customer service (D3.5).
- Efficiency and benefit of digital supply chain: Mainly assess the overall performance and value performance of digital supply chain from the aspects of 4 sub-dimensions, including flexibility of digital supply chain (D4.1), resilience of digital supply chain (D4.2), risk prevention and control of digital supply chain (D4.3) and comprehensive performance of digital supply chain (D4.4).

8.2 System design of digital supply chain

8.2.1 Initial starting level (L1)

At initial starting level (L1), the characteristics of strategic planning, organizational structure, cooperation mode, network structure and capability layout of the supply chain are as follows:

- Tasks related to supply chain operations should be set in the department-level strategic plan, and the implementation of tasks related to supply chain should be tracked and evaluated.
- Personnel and positions to perform supply chain management responsibilities should be instituted, and relevant personnel should have basic knowledge of supply chain management and operation skills of digital tools and can use information technology and digital tools to carry out standardized and process-based management and control of supply chain business.
- Clear selection criteria and cooperation rules for suppliers, manufacturers, service providers and distributors should be established.
- Linear and serial chain-like supply chain structure should be planned and formed, and the addresses of key nodes in the supply chain such as supply, production, logistics, and sales should be clearly defined.

- Material, manpower, equipment and other resources and capacity, warehousing, logistics and other capabilities of key nodes in the supply chain should be rationally planned and allocated in combination with the network structure of the supply chain.

8.2.2 Unit optimization level (L2)

At unit optimization level (L2), the characteristics of strategic planning, organizational structure, cooperation mode, network structure and capability layout of the supply chain are as follows:

- Strategic tasks and assessment objectives related supply chain should be set in the strategic plan, and corresponding support resources such as people, finances, and materials should be matched, so that the supply chain strategic tasks can be tracked and evaluated.
- Full-time departments and positions for supply chain management should be established, and relevant personnel with skills in supply chain management and information technology applications should be provided to carry out digital management of core business units of the supply chain.
- Scientific selection criteria and cooperation rules for suppliers, manufacturers, service providers and distributors should be established, and stable cooperative relations should be established with core partners.
- Multisource and single chain supply chain structures should be constructed, and the addresses of key supply chain nodes such as supply, production, logistics, and sales should be clarified and adjusted.
- The materials, manpower, equipment and other resources and production capacity, warehousing, logistics and other capabilities of key nodes in the supply chain should be reasonably configured and timely adjusted according to the business needs and the supply chain network structure.

8.2.3 Integrated collaboration level (L3)

At integrated collaboration level (L3), the characteristics of strategic planning, organizational structure, cooperation mode, network structure and capability layout of the supply chain are as follows:

- Supply chain strategy should be formulated, and a complete support system of supply chain strategy based on digital technology should be created to achieve the coordination and synergism of the overall strategy, supply chain strategy and other functional strategies.
- Specialized departments and positions for supply chain management should be established, and professionals with supply chain management capabilities, information technology applications, data analysis and mining and other digital skills should be equipped, who can cooperate with production, logistics, sales and information departments to carry out digital management covering the entire process of the enterprise supply chain.
- Appropriate suppliers, manufacturers, service providers, and distributors should be scientifically selected and introduced, and consensus with supply chain partners should be reached among operating rules such as supply chain business collaboration, information exchange, and mutual profit.
- Multisource and single chain supply chain structures should be formed, and networked connections should be realized at each node of the supply chain, which can design and optimize key supply chain nodes such as supply, production, logistics, and sales based on data analysis.
- Materials, manpower, equipment and other resources and production capacity, warehousing, logistics and other capabilities of key nodes in the supply chain should be scientifically configured and precisely optimized based on data analysis, according to the

business needs of the enterprise, changes in market demand, resource structure adjustment and other factors.

8.2.4 Full-chain collaboration level (L4)

At full-chain collaboration level (L4), the characteristics of strategic planning, organizational structure, cooperation mode, network structure and capability layout of the supply chain are as follows:

- With the goal of optimizing the overall operation of the supply chain, the digital supply chain strategy and its implementation plan should be formulated and adjusted, and collaboratively formulated, implemented and optimized with the upstream and downstream of the supply chain.
- Supply chain collaboration mechanisms should be established for upstream and downstream suppliers, manufacturers, service providers, distributors and consumers in the supply chain, and the whole process management and optimization of the upstream and downstream business of the supply chain should be carried out collaboratively based on the platform.
- Suppliers, manufacturers, service providers, distributors and other upstream and downstream partners in the supply chain should be selected, managed, assessed and adjusted, and a cooperative relationship of information sharing, risk sharing and mutual benefit should be established with partners.
- Network supply chain structure of consumer-centre, multi-source parallel of partners' business flow, logistics, data flow and capital flow should be established, which can dynamically optimize the overall structure of the supply chain network and the layout of key supply chain nodes such as supply, production, logistics, and sales based on models according to the flexibility and resilience requirements of the supply chain.
- A supply chain capacity allocation model should be constructed to scientifically allocate and dynamically optimize materials, manpower, equipment and other resources and capacity, warehousing, logistics and other capabilities of key nodes in the supply chain based on factors such as business needs, changes in market demand, and resource structure adjustments.

8.2.5 Ecosystem intelligence level (L5)

At ecosystem intelligence level (L5), the characteristics of strategic planning, organizational structure, cooperation mode, network structure and capability layout of the supply chain are as follows:

- Based on the positioning of the digital supply chain ecosystem, a unified digital supply chain ecosystem strategy oriented by value co-creation should be formulated in coordination with partners in the supply chain ecosystem, and the strategy should be uniformly matched and dynamically adjusted at the business department, key nodes, the whole supply chain and other levels.
- The physical boundaries should be broken to establish a cross-business operation organization for a digital supply chain ecosystem with partners in the supply chain ecosystem and external stakeholders, and the overall scheduling and dynamic management of business, funds, materials, and data in supply chain ecosystem should be carried out based on the platform.
- Partners in a supply chain ecosystem should be identified, introduced, managed and dynamically adjusted according to the development needs of a digital supply chain ecosystem, and cooperative relationships of data sharing, business collaboration, resource collaboration, and model innovation should be established cooperating with partners and external stakeholders.

- A supply chain ecosystem with consumer-centre and comprehensive business connections, data connections and value connections with supply chain partners and external stakeholders should be established, and on the basis of the evaluation and prediction of key performances such as supply chain flexibility and toughness, intelligent modelling, simulation, data mining and other means should be used to adaptively match and dynamically optimize the overall ecosystem structure of the supply chain and the key node layout of supply chains such as supply, production, logistics, and sales.
- The materials, manpower, equipment and other resources and production capacity, warehousing, logistics and other capabilities at different nodes of the supply chain ecosystem should be simulated, configured, predicted and optimized using simulation, intelligent modelling and other means by comprehensive analysis of partner data in the supply chain ecosystem and external market information.

8.3 Platform empowerment of digital supply chain

8.3.1 Initial starting level (L1)

At initial starting level (L1), the characteristics of enabling technologies, data management, data models, and information traceability around the supply chain are as follows:

- Digital tools such as enterprise resource planning (ERP) should be deployed to support standardized online management of some business processes in supply chain.
- The necessary supply chain data should be recorded, stored and managed.
- The necessary supply chain basic data should be counted.
- Products, materials, equipment and other supply chain entities should be uniquely identified.

8.3.2 Unit optimization level (L2)

At unit optimization level (L2), the characteristics of enabling technologies, data management, data models, and information traceability around the supply chain are as follows.

- Digital tools such as enterprise resource planning (ERP), supplier relationship management (SRM), customer relationship management (CRM) and warehouse management system (WMS) should be deployed as required, and automation equipment such as industrial robots, automated production lines, automated guided vehicle (AGV) and automated warehouses should be applied to support the automatic execution of key business units of supply chain such as plan, procurement, production, delivery and services.
- Major supply chain data such as demand, order, plan, procurement, production, logistics, inventory and services should be collected regularly and standardized stored and managed in a digital way.
- Statistical analysis of main supply chain data such as demand, order, plan, procurement, production, logistics, inventory, and service should be realized, and the operation of the main business units of the supply chain should be displayed in a visual form.
- Entity objects such as products, materials, equipment and non-entity objects such as orders and services should be uniquely identified.

8.3.3 Integrated collaboration level (L3)

At integrated collaboration level (L3), the characteristics of enabling technologies, data management, data models, and information traceability around the supply chain are as follows:

- An integrated digital platform that supports the core business of the supply chain should be deployed, which can connect automation equipment such as industrial robots, automated production lines, AGV, automated warehouses, and other related business systems of the

enterprise, and support integrated management and control of core business such as supply chain plan procurement, production, delivery and services.

- A supply chain data resource standard system should be established to comprehensively collect, manage and end-to-end integrate supply chain data such as demand, order, plan, procurement, production, logistics, inventory and services.
- Supply chain data association analysis and in-depth mining of demand, order, plan, procurement, production, logistics, inventory and services should be carried out based on a digital platform, and the operation situation and trend of supply chain should be presented in a visual form.
- A supply chain information traceability system should be established to uniquely identify and forward track products, materials, equipment, orders, businesses and other objects.

8.3.4 Full-chain collaboration level (L4)

At full-chain collaboration level (L4), the characteristics of enabling technologies, data management, data models, and information traceability around the supply chain are as follows:

- An integrated digital platform with functions such as supply chain system design, business operation, risk management and control, and performance management should be deployed and applied, and integrate the relevant business systems of supply chain partners and automation equipment such as production, warehousing, and distribution to support the integrated management, control and collaborative operation of the entire supply chain business.
- A unified supply chain data resource standard system and data security protection mechanism should be established with supply chain partners to realize the dynamic perception, real-time interaction and hierarchical and classified management of data in the whole supply chain based on the platform.
- Based on the digital platform, of your own and of supply chain partners, professional knowledge, business rules and industrial mechanisms should be encapsulated as needed to form a supply chain knowledge base and model base, and to form real-time analysis and model application capability of the whole supply chain data.
- A unified supply chain traceability system should be established with supply chain partners to carry out forward and reverse tracing of the whole of supply chain information from raw material procurement, production and manufacturing, warehousing and logistics to terminal sales based on the platform.

8.3.5 Ecosystem intelligence level (L5)

At ecosystem intelligence level (L5), the characteristics of enabling technologies, data management, data models, and information traceability around the supply chain are as follows:

- A unified digital supply chain technology architecture and service platform should be constructed with partners in the supply chain ecosystem, and should integrate related business systems and automation equipment of supply chain ecosystem partners and be interconnected with relevant e-commerce platforms, industrial Internet platforms, industrial supermarkets and other social systems to support intelligent operation of business in the supply chain ecosystem, dynamic allocation of resources and collaborative innovation of models.
- Unified digital supply chain ecosystem architecture, as well as the asset management and data protection mechanisms should be established with partners in the supply chain ecosystem and external interests based on the platform to implement the dynamic perception, real-time interaction and safety protection of the data in the supply chain ecosystem and form a complete content, safe and reliable calculation, analysis of the ecosystem data link of the supply chain.

- A digital twin of the supply chain ecosystem should be established based on the digital platform, so that full scene digitalization of business activities in the supply chain ecosystem can be carried out. With digital mapping and modular combination of the resources, abilities and knowledge of partners in the supply chain ecosystem and external stakeholders, the digital twin can be used to realize the real-time analysis, accurate description, collaborative optimization and automatic prediction of activities in the supply chain ecosystem.
- A unified traceability system in the supply chain ecosystem should be established with supply chain partners and external stakeholders, and identification analysis, Internet of things (IoT), blockchain and other information technologies should be used to realize real-time tracking, rapid traceability and accurate prediction of the whole supply chain and product life cycle information.

8.4 Business operation of digital supply chain

8.4.1 Initial starting level (L1)

At initial starting level (L1), the characteristics of planning and forecasting of supply chain, diversified sourcing and procurement, intelligent production management, precise delivery of orders and digital customer service are as follows:

- The procurement plan, production plan and logistics plan should be made regularly.
- A qualified supplier management mechanism and a standardized procurement process should be established and implemented effectively.
- Production should be scheduled legitimately according to production plan and ordered information production operations should be carried out according to plan.
- Unified recording and maintenance of basic order information should be carried out to achieve standardized management of warehousing and logistics and orderly delivery of orders.
- Various after-sales service channels should be provided, standardized service processes should be created, and customer service data should be regularly tracked and statistically analysed.

8.4.2 Unit optimization level (L2)

At unit optimization level (L2), the characteristics of planning and forecasting of supply chain, diversified sourcing and procurement, intelligent production management, precise delivery of orders and digital customer service are as follows:

- A procurement plan, production plan and logistics plan should be made using digital tools, and the implementation of the supply chain plan can be tracked and can provide feedback.
- The source search, evaluation and management of suppliers should be carried out using digital tools, and the online implementation and tracking of procurement processes should be realized.
- According to the production plan and order information, the production plan should be worked out scientifically and the production task should be executed efficiently, and provide tracking and visualization of the production operation process in real time.
- The basic order information should be recorded, tracked and maintained using digital tools to achieve efficient execution and visual management of product warehousing, warehousing, and inventory and logistics distribution, so as to achieve on-time delivery of orders.

- Timely after-sales service for customers should be provided using digital tools, and there should be regular tracking and statistics of customer service data, and feedback to R&D, production, logistics and other departments.

8.4.3 Integrated collaboration level (L3)

At integrated collaboration level (L3), the characteristics of planning and forecasting of supply chain, diversified sourcing and procurement, intelligent production management, precise delivery of orders and digital customer service are as follows:

- The market demand analysis should be carried out based on the digital platform, and the procurement plan, production plan and logistics plan should be formulated and executed collaboratively, so as to realize the coordination and unity of the procurement progress, production scheduling plan, production rhythm, and logistics scheduling, and be able to dynamically track the implementation of the plan, and dynamically adjust purchasing, production and logistics plans in response to demand fluctuations and resource changes.
- Potential suppliers should be identified based on the digital platform, and the whole life-cycle management of supplier sourcing, certification, evaluation and withdrawal should be carried out, and realized in the online execution, tracking and timely adjustment of the whole process of procurement.
- The digital platforms should be used according to the production plan and order information to automatically generate production scheduling plans, allocate production resources such as equipment, personnel and materials as needed so as to accurately execute production tasks, and realize the real-time monitoring and timely optimization of production takt *(production pace or rhythm)*, production progress, and order allocation according to production tasks and environmental changes.
- The order status, execution, delivery, change and other information should be recorded, tracked and maintained based on the digital platform, and the coordinated operation and digital control of the whole process of warehousing and logistics should be carried out by automated storage systems and logistics equipment, so as to achieve on-time delivery of orders.
- R&D, production, logistics and other resources should be integrated to establish an integrated customer service system, and to carry out whole-process tracking and collaborative execution of customer services to ensure convenient, timely and reliable customer services.

8.4.4 Full-chain collaboration level (L4)

At full-chain collaboration level (L4), the characteristics of planning and forecasting of supply chain, diversified sourcing and procurement, intelligent production management, precise delivery of orders and digital customer service are as follows:

- Market demand forecasting should be carried out with supply chain partners based on the digital platform, and should collaboratively formulate production plans, logistics plans and procurement plans, and coordinate the upstream and downstream procurement progress, production scheduling plan, production takt, logistics scheduling and sales progress of the supply chain, and should achieve supply chain planning collaborative linkage and dynamic optimization based on data.
- Potential suppliers should be accurately identified based on the digital platform. Furthermore, an appropriate supplier resource pool and supply resource network should be established, and key supply nodes should be backed up as needed. Moreover, dynamic management of suppliers' whole life cycle, as well as tracking, control and optimization of the whole process of procurement execution should be carried out based on data.

- According to the production plan, an order information and demand forecast, production scheduling plan should be formulated, executed and optimized collaboratively with supply chain partners based on the digital platform, and should accurately simulate, analyse and predict the upstream and downstream production processes of the supply chain based on data, and should realize the dynamic configuration and flexible adjustment of upstream and downstream production tasks and manufacturing resources in the supply chain.
- The order life-cycle information should be managed, tracked and maintained collaboratively with supply chain partners based on the digital platform, and a warehouse model and distribution model should be deployed and applied. Based on the model, inventory status, logistics network, distribution route and mode of transportation can be monitored, managed and optimized, so as to achieve on-time delivery of orders.
- A digital service system covering online and offline channels should be established with supply chain partners, and should carry out customer portraiting and difference analysis based on data, and should provide a customized and transparent whole process of pre-sale, sale and after-sales service.

8.4.5 Ecosystem intelligence level (L5)

At ecosystem intelligence level (L5), the characteristics of planning and forecasting of supply chain, diversified sourcing and procurement, intelligent production management, precise delivery of orders and digital customer service are as follows:

- A coordinated operation plan of the supply chain ecology should be formed based on the digital platform and partners of the supply chain ecology on the basis of demand forecasting, and the collaborative implementation of production, logistics, procurement and other plans should be carried out. The implementation process of the plan can be simulated and predicted by means of simulation and digital twins, so as to realize the independent decision-making and adaptive adjustment of the operation plan of the supply chain ecology.
- The procurement model and supplier evaluation model should be deployed based on the digital platform, potential suppliers should be identified and matched independently based on the model, diversified supplier resource pools and supply resource networks should be constructed and dynamically adjusted, and key supply nodes should be backed up automatically, and should carry out dynamic tracking, collaborative execution and independent optimization of the whole procurement process with partners of the supply chain ecology.
- Intelligent scheduling algorithms and models should be deployed on the digital platform, which can automatically generate and independently optimize the overall scheduling plan of the supply chain ecology according to production planning, order information and demand forecast, and should simulate, analyse and predict the manufacturing resource allocation, production execution process and operation fluctuation of the supply chain ecology, and be able to carry out cross-regional and cross-enterprise capacity sharing and collaborative production among partners of the supply chain ecology.
- Collaborative management, dynamic tracking and unified maintenance of order life-cycle information should be carried out with partners of the supply chain ecology and external stakeholders based on the digital platform, and a digital warehousing and logistics system should be established. Independent matching and adaptive optimization of optimal order delivery schemes covering products, warehouses, vehicles and routes, should be carried out so as to achieve efficient and accurate order delivery.
- An all-channel digital service system which can accurately reach end customers should be established with supply chain partners and external stakeholders. Based on the digital platform, a customer resource base, product fault knowledge base and maintenance method base should be deployed. Based on models, customer service demand should be predicted,

service resources should be dynamically allocated, and product online monitoring, fault diagnosis, remote operation and maintenance, data value-added and other innovative services should be carried out synergistically.

8.5 Efficiency and benefit of digital supply chain

8.5.1 Initial starting level (L1)

At initial starting level (L1), the characteristics of flexibility of digital supply chain, resilience of digital supply chain, risk prevention and control of digital supply chain and comprehensive performance of digital supply chain are as follows:

- Business activities and resource input related the supply chain, as well as the type and number of products and services should be adjustable, and the supply chain system can respond to changes in market demand.
- The necessary alternative production capacity and material safety inventory should be allocated, and the supply chain system should operate smoothly under normal conditions.
- The main risk factors of the supply chain should be perceived and identified, and the risk management plan should be formulated and implemented effectively.
- Necessary supply chain performance indicators such as just-in-time delivery rate and inventory turnover rate should be measured and recorded.

8.5.2 Unit optimization level (L2)

At unit optimization level (L2), the characteristics of flexibility of digital supply chain, resilience of digital supply chain, risk prevention and control of digital supply chain and comprehensive performance of digital supply chain are as follows:

- Used digital tools, and business processes such as purchasing, manufacturing, logistics and distribution should be changed as needed, resources such as materials, equipment, personnel and funds should be dispatched, and the variety and quantity of products and services should be optimized, and the supply chain system can effectively respond to changes in market demand.
- Used digital tools, alternative production capacity, manpower reserves and a material safety inventory should be planned and allocated, and the supply chain system should operate smoothly under normal conditions and have the ability to recover effectively under abnormal conditions.
- Used digital tools, the risk factors and types of the supply chain should be fully perceived and identified, the degree and root causes of the risk should be assessed, and the risk disposal plans should be scientifically formulated and implemented to achieve an effective response to the main risks of the supply chain.
- Used digital tools, the main performance indicators of supply chain should be monitored and evaluated regularly, and the relevant departments of the supply chain should be assessed so that the operation of the supply chain can achieve the expected value and benefit.

8.5.3 Integrated collaboration level (L3)

At integrated collaboration level (L3), the characteristics of flexibility of digital supply chain, resilience of digital supply chain, risk prevention and control of digital supply chain and comprehensive performance of digital supply chain are as follows:

- Based on the digital platform, the business processes such as purchasing, manufacturing, logistics and distribution, and customer service should be changed, materials, equipment, personnel, funds and other resources should be dynamically scheduled, and the variety,

quality and quantity of products and services should be optimized. The supply chain system can respond to changes in market demand in a timely manner.

- Based on the digital platform, appropriate alternative production capacity, guarantee funds, manpower reserves and a material safety inventory should be planned and configured, and the backup of major nodes in the supply chain, such as supply, production, logistics and sales, should be carried out. The supply chain system maintains continuous operation under normal conditions, and has the ability to respond and recover quickly under abnormal conditions.
- Based on the digital platform, the supply chain risk factors and types should be perceived and identified in real time, the probability, time, degree and root causes of the supply chain risk should be quantitatively evaluated, and a cross-departmental and cross-functional risk prevention and control mechanism and disposal scheme should be constructed to achieve timely control and effective response to the main risks of the supply chain.
- Relying on the digital platform, the supply chain performance evaluation system should be deployed, so as to the main supply chain performance indicators such as just-in-time delivery rate, inventory turnover rate, market share and customer satisfaction can be monitored, evaluated and analysed in real time, and the relevant departments and personnel of the supply chain can be comprehensively assessed to form a closed-loop supply chain performance improvement mechanism to achieve the continuous creation of the value and benefit of the supply chain.

8.5.4 Full-chain collaboration level (L4)

At full-chain collaboration level (L4), the characteristics of flexibility of digital supply chain, resilience of digital supply chain, risk prevention and control of digital supply chain and comprehensive performance of digital supply chain are as follows:

- The supply chain flexibility evaluation model should be deployed, and the overall supply chain flexibility should be evaluated with supply chain partners based on the model. Furthermore, relying on the digital platform, the supply chain network structure and business process should be jointly adjusted, materials, equipment, personnel, funds and other resources should be coordinated, and the variety, quality and quantity of products and services should be changed rapidly. The supply chain system can respond quickly to market changes and diversified customer needs.
- The supply chain resilience evaluation model should be deployed, the overall resilience of the supply chain should be evaluated with supply chain partners based on the model, the supply chain alternative capacity, ensure capital, manpower reserves and a material safety inventory should be synergistically planed, configured, optimized, and diversified backup of supply chain nodes can be carried out. The supply chain system maintains continuous operation under normal conditions, and has the ability for a dynamic response and recovery under an uncertain environment.
- The supply chain risk hierarchical assessment model should be deployed based on the digital platform, and the systemic risk and local risk of the supply chain should be perceived with supply chain partners based on the model, and the probability, time, degree and root causes of the risk should be accurately evaluated and scientifically diagnosed, so as to form a joint risk prevention and control mechanism and disposal plan across enterprises to achieve hierarchical regulation and a linkage response to the overall risk of the supply chain.
- Relying on the digital platform, a supply chain performance evaluation model should be established with supply chain partners, and the plan execution rate, just-in-time delivery rate, inventory turnover rate, market share, customer satisfaction and other performance indicators of supply chain partners and the overall supply chain should be monitored,

evaluated, analysed and assessed to form a continuous optimization mechanism of the overall performance of the supply chain to achieve the continuous optimization of the overall value and benefit of the supply chain.

8.5.5 Ecosystem intelligence level (L5)

At ecosystem intelligence level (L5), the characteristics of flexibility of digital supply chain, resilience of digital supply chain, risk prevention and control of digital supply chain and comprehensive performance of digital supply chain are as follows.

- The supply chain flexibility evaluation and prediction model should be deployed, the overall flexible performance of the supply chain can be evaluated, predicted and optimized with supply chain partners and external stakeholders based on the model, the network structure and business process of the supply chain ecology should be dynamically reconstructed based on the digital platform, the ecological and social resources of the supply chain should be dispatched across regions, and the variety, quality and quantity of products and services can be changed dynamically. The supply chain system has the ability of self-optimization for rapid market change and diversified customer needs.
- The supply chain toughness evaluation and prediction model should be deployed, and the overall toughness performance of the supply chain can be evaluated, predicted and optimized with supply chain partners and external stakeholders based on the model. Furthermore, relying on the digital platform, partners and social resources and capabilities can be transferred, and alternative capacity, guarantee funds, manpower reserves and material safety inventory of the supply chain ecology can be scientifically planed, dynamically allocated, and precisely optimized, so as to realize the diversified backup of the supply chain ecology nodes. The supply chain ecology can maintain the continuous operation of the supply chain ecosystem under normal conditions, and have the ability of self-adaptation, self-adjustment and self-recovery in an uncertain environment.
- The supply chain risk assessment and prediction model, as well as the supply chain risk characteristic database and disposal plan database should be deployed with supply chain partners and external stakeholders based on the digital platform, and a model-driven integrated prevention and control mechanism of risk dynamic perception, accurate assessment, linkage disposal and advance early warning of the supply chain ecology can be formed with partners of the supply chain ecology and external stakeholders to achieve pre-response, accurate control and efficient response to risks to the supply chain ecology.
- Relying on the digital platform, the performance evaluation and prediction model of the supply chain ecology should be built together with partners of the supply chain ecology, and the plan execution rate, just-in-time delivery rate, inventory turnover rate, market share, customer satisfaction and popularization of the new model and other performance indicators of the supply chain ecology partners, and the overall the supply chain ecology can be real-time monitored, dynamically evaluated, deeply analysed, precisely predicted and comprehensively assessed. A continuous optimization mechanism and improvement scheme for the performance of the supply chain ecology can also be formed, so as to realize the continuous optimization of the overall value benefit of the supply chain ecology, and produce high added value through model innovation.

9 Maturity assessment methods

9.1 Collection of assessment evidence

According to the expected maturity level of digital supply chain, the assessment evidence of the corresponding maturity level of digital supply chain should be collected in an appropriate way, including interview, observation, on-site inspection, document and records review, system demonstration, and data collection, etc.

9.2 Calculation of assessment score

9.2.1 Determination of score of sub-dimensions

According to the conformity degree between the collected evidence and the maturity dimensions, the score of each maturity sub-dimension should be determined. Among them, the conformity is recommended to be recorded as 1, the basic conformity is recommended to be recorded as 0.8, the partial conformity is recommended to be recorded as 0.5, and the non-conformity is recommended to be recorded as 0.

9.2.2 Setting of weights

Weights should be assigned to the maturity dimension and the maturity sub-dimension according to the type and nature of digital supply chain.

Experienced experts can be invited to discuss weights. The Delphi method, analytic hierarchy process and network analysis can be used to determine the weight of each dimension and sub-dimension.

9.2.3 Calculation of overall score

The score B of the maturity dimension is the weighted sum of the scores of the maturity sub-dimensions under the dimension, and the score of the maturity dimension is calculated according to Equation (1):

$$B = \sum(C \times \beta) \tag{1}$$

where,

B: score of the maturity dimension

C: score of the maturity sub-dimension

β: weight of the maturity sub-dimension.

The overall score A is the weighted sum of the scores of each maturity dimension, and the overall score is calculated according to Equation (2):

$$A = \sum(B \times \alpha) \tag{2}$$

where,

A: overall score

B: score of the maturity dimension; and

α: weight of the maturity dimension.

9.3 Determination of maturity level

The relevant stakeholders are recommended to set their own score. For example, if the overall score and the score of each dimension are higher than 0.8, it is judged that the digital supply chain maturity meets the corresponding level. Otherwise, it is judged that it does not meet the corresponding level.

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