INTERNATIONAL STANDARD

ISO 22549-2

First edition
2020-10

Automation systems and integration — Assessment on convergence of informatization and industrialization for industrial enterprises —

Part 2: Maturity model and evaluation methodology

Systèmes d'automatisation et d'intégration — Évaluation de la convergence de l'informatisation et de l'industrialisation pour les entreprises industrielles —

Partie 2: Modèle de maturité et méthodologie d'évaluation

Reference number
ISO 22549-2:2020(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 05, *Interoperability, integration, and architectures for enterprise systems and automation applications*.

A list of all parts in the ISO 22549 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Convergence of informatization and industrialization (CII) refers to a process that integrates information technology into industrial production. The purpose of convergence is to improve productivity and resource allocation by digital transformation.

This improvement consists of:

— increasing the integration of production and resource allocation (internally and with each other);

— making production and resource allocation more dynamic and responsive to external changes;

— optimizing production and resource allocation.

The purposes of this document include is to provide industrial enterprises guidance for:

— assessing the current situation of CII

— finding weakness within the CII

— identifying ways to improve CII

The intended users of this document can be grouped into the following categories:

— independent third-party, e.g. a consulting company or government department, that assesses the maturity of CII;

— organization in charge of production management department, quality management department, inventory management department, etc., which sponsors an assessment of itself or a subordinate organization;

— any other enterprises who have interest in digital transformation.

Automation systems and integration — Assessment on convergence of informatization and industrialization for industrial enterprises —

Part 2:
Maturity model and evaluation methodology

1 Scope

This document defines the maturity model and the evaluation methodology on convergence of informatization and industrialization in industrial enterprises. The scope of this document includes the following:

— maturity model definition;

— principles of evaluation questionnaires; and

— guidance for a maturity evaluation method.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 22549-1, *Automation systems and integration — Assessment on convergence of informatization and industrialization for industrial enterprises — Part 1: Framework and reference model*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 22549-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
maturity model
set of information that indicate the maturity of CII, its descriptive name and characteristics

3.2
maturity level indicator
maturity level
identified extent of measured effect within the *maturity model* (3.1)

Note 1 to entry: The extent of measured effect is divided into segments, referred to as levels, of increasing competence to achieve enterprise objectives.

3.3
evaluation questionnaire
list of questions used to evaluate and determine the *maturity level* (3.2)

3.4
maturity evaluation
method for determining the *maturity level* (3.2) of an industrial enterprise using responses to the *evaluation questionnaire* (3.3)

4 Abbreviated terms

ACII	assessment on convergence of informatization and industrialization
BOM	bill of material
CAD	computer aided design
E-BOM	engineering BOM
ECO	engineering change order
EHS	environment, safety and health
ERP	enterprise resource planning
IT	information technology
M-BOM	manufacturing BOM
MES	manufacturing execution system
PLM	product lifecycle management
SPC	statistical process control
WIP	work in process

5 Maturity model

The maturity model consists of maturity levels where each level consists of a maturity level indicator, descriptive name, and characteristics relevant to the desired assessment information as shown in Table 1. These characteristics guide to create questions to evaluate maturity levels, which are given in Annex as examples.

Table 1 — Maturity model definition

Maturity level indicator	Descriptive name	Characteristics
Level 0	Unidentified	Little or no systematic documentation available
Level 1	Identified	Tracking and traceability of materials, data and etc.
		Registration and management of data using information collection devices and systems
Level 2	Measured	Real time data acquisition of materials, machinery, process and human roles, and data integration
		Measurement, aggregation, classification and management of data using information collection devices and systems
		Synchronous history of data for the same time, same lot and same product
Level 3	Analysed	Data analysis based on aggregated data for support of decision making

Table 1 *(continued)*

Maturity level indicator	Descriptive name	Characteristics
Level 4	Optimized	Optimized automation of processes throughout the intra-enterprise and/or the inter-enterprises
Level 5	Autonomous	Self-diagnosis and self-healing through cyber-physical system (CPS), Internet of Things (IoT), artificial intelligence (AI), etc.
		Flexible production of customized products through autonomous control

NOTE Because maturity level 0 is the same for every questionnaire table, level 0 is not included in the separate tables.

Each maturity level is inclusive of the lower maturity levels (see Figure 1), such that the higher maturity level also includes all the characteristics of the lower levels.

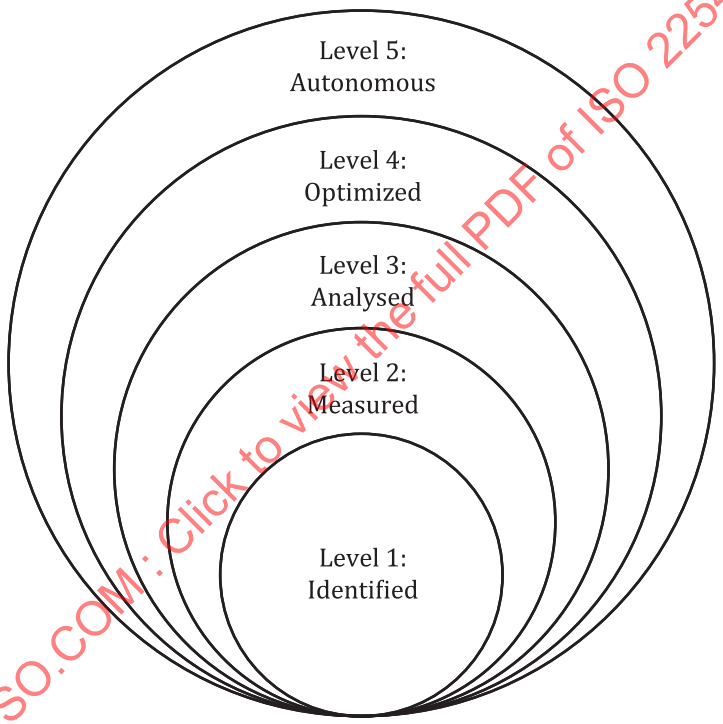

Figure 1 — Maturity level (inclusive)

Assessment of maturity level is done by evaluating assessment on convergence of informatization and industrialization (ACII) reference model components based on the answers to the evaluation questions.

6 Principles of evaluation questionnaires for ACII reference model components

6.1 General

Figure 2 presents assessment reference model defined in ISO 22549-1. Four aspects are grouped by the blue-dotted line which twenty-four subordinate components to four aspects are grouped by the red-dotted line.

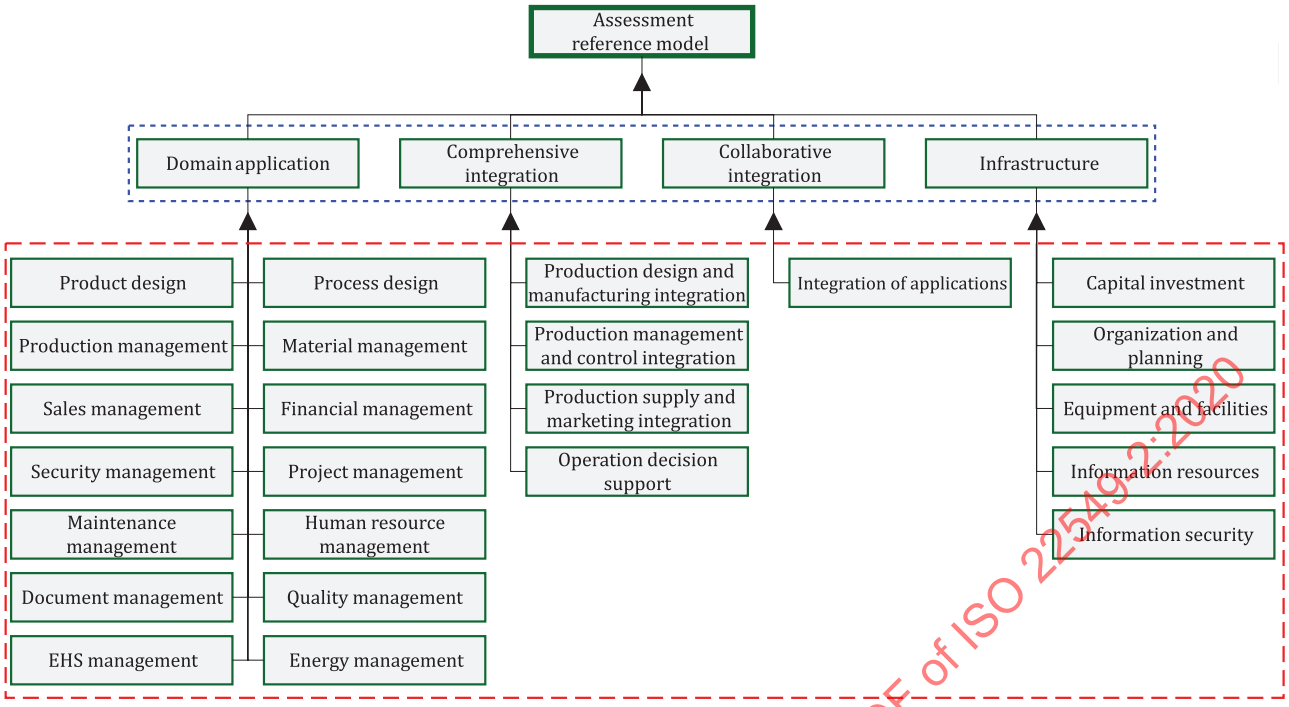

Figure 2 — Assessment reference model (aspect and its subordinate component)

In general, each ACII reference model component consists of one or more activities, for example, product design requires commodity planning, design automation, bill of material (BOM)/Parts management, engineering change management, etc.

For ACII, each ACII reference model component has to be evaluated in the level of its activities, and each activity has a set of questions to answer for each maturity level. Question answers shall be "YES" or "NO."

Evaluation of maturity level using questionnaires is well-known and a common way, since it is easy to make answers to the given questions and evaluate the maturity level based on the answers.

Table 2 shows the structure of questions for evaluation.

Table 2 — Structure of question for maturity evaluation

Activity	Question	Maturity level indicator
Activity name 1	Questions for maturity level 1.	1
	Questions for maturity level 2.	2
	Questions for maturity level 3.	3
	Questions for maturity level 4.	4
	Questions for maturity level 5.	5

Table 2 *(continued)*

Activity	Question	Maturity level indicator
Activity name 2	Questions for maturity level 1.	1
	Questions for maturity level 2.	2
	Questions for maturity level 3.	3
	Questions for maturity level 4.	4
	Questions for maturity level 5.	5
Activity name...	Questions for maturity level 1.	1
	Questions for maturity level 2.	2
	Questions for maturity level 3.	3
	Questions for maturity level 4.	4
	Questions for maturity level 5.	5
Activity name N	Questions for maturity level 1.	1
	Questions for maturity level 2.	2
	Questions for maturity level 3.	3
	Questions for maturity level 4.	4
	Questions for maturity level 5.	5

— **Activity**:

Activity of ACII reference model component.

This document specifies a number of activities to be evaluated for each ACII reference model component.

— **Question**:

Questions to assess maturity level satisfaction, and the answer shall be “YES” or “NO”.

All questions in all activities in a given level need to be evaluated and all must be “YES” to proceed to the next level questions by applying guidance for maturity evaluation method given in 7.

Annex A gives examples of a whole set of questions for all ACII reference model components.

— **Maturity level indicator**:

Maturity level used for maturity evaluation.

6.2 Activity of ACII reference model component for evaluation

6.2.1 Infrastructure aspect assessment

6.2.1.1 Capital investment

Capital investment should be evaluated in terms of construction of automation and informatization, operation and maintenance of the information system as shown in Table 3.

Table 3 — Activity of capital investment for evaluation

Activity	Description
Capital investment	Investment to the IT equipment and systems

6.2.1.2 Organization and planning

Organization and planning should be evaluated in terms of team of personnel, establishment of the organization, authority and defining of strategy related to the field of automation and informatization as shown in Table 4.

Table 4 — Activity of organization and planning for evaluation

Activity	Description
Organization and planning	Team, organization, authority and strategy for automation and informatization

6.2.1.3 Equipment and facilities management

Equipment and facilities management should be evaluated in terms of management of information equipment and facilities, industrial equipment and facilities as shown in Table 5.

Table 5 — Activity of equipment and facilities management for evaluation

Activity	Description
Equipment and facilities management	Management of information and industrial equipment and facilities

6.2.1.4 Information resources management

Information resources management should be evaluated in terms of construction of the information resources as shown in Table 6.

Table 6 — Activity of information resources management for evaluation

Activity	Description
Information resources management	Collection, standardization, accumulation, integration, analysis, and management of information resources

6.2.1.5 Information security management

Information security management should be evaluated in terms of protection of information security as shown in Table 7.

Table 7 — Activity of information security management for evaluation

Activity	Description
Computer and network security management	Implementation of protection of computer and networking security
System and application security management	Implementation of protection of system security, application security and construction of the prevention mechanism

6.2.2 Domain application aspect assessment

6.2.2.1 Product design

Product design should be evaluated in terms of digitalized model of the product, digital examination, comprehensive design and optimization, and intelligent design of a product as shown in Table 8.

Table 8 — Activity of product design for evaluation

Activity	Description
Design environment analysis	Analysis of IT environment for product design to collect and analyse product design information
Product planning	Process of identifying and articulating market requirements that define a product's feature set such as creation of a product idea, price, distribution and promotion, etc
Design automation	Use of designing software systems and smart connected technology for design such as computer aided design (CAD), computer aided engineering (CAE), augmented reality and virtual reality
BOM/parts management	Management of both engineering BOM (E-BOM) and manufacturing BOM (M-BOM) using IT systems
Engineering change management	Management of both engineering change order (ECO) and engineering change request (ECR) using IT systems
Prototyping	Use of IT systems and applications for prototyping and its validation
Advance quality management	Quality management of product in prototyping stage

6.2.2.2 Process design

Process design should be evaluated in terms of design of process flow or planning, analysis of dynamic simulation, process control and parameter optimization and integrated process design as shown in Table 9.

Table 9 — Activity of process design for evaluation

Activity	Description
Process design	Use of IT systems and applications for supporting design of process flow or planning, analysis of dynamic simulation, process control and parameter optimization and integrated process design

6.2.2.3 Production management

Production management should be evaluated in terms of production planning and scheduling, production management, material requirement planning, distribution management, and outsource planning and management as shown in Table 10.

Table 10 — Activity of production management for evaluation

Activity	Description
Master production scheduling	Use of IT systems and applications for scheduling master production, and optimization and customization
Work in process (WIP) management	Use of IT systems and applications for managing work-in-process
Monitoring and control	Use of IT systems and applications for monitoring and controlling production
Process control	Use of IT systems and applications for automatic process control, and optimization and customization
Process analysis and enhancement	Use of IT systems and applications for process analysis and enhancement

6.2.2.4 Materials management

Material management should be evaluated in terms of purchasing, inbound logistics, and management of suppliers in the materials management of product as well as the e-commerce purchasing as shown in Table 11.

Table 11 — Activity of materials management for evaluation

Activity	Description
Material order	Use of IT systems and applications for integrated material order with master production schedule, BOM and inventory status, etc
Material receipt	Use of IT systems and applications for management of received material
Warehouse management	Use of IT systems and applications for managing warehouse and optimization
Weighing management	Use of IT systems and applications for weighing management, and automatic calibration
Material release and process input	Use of IT systems and applications for material release and process input, and integration with production control system

6.2.2.5 Sales management

Sales management should be evaluated in terms of management of sales, management of the inventory of finished products, logistics distribution, after-sales services and management of suppliers in the sales management of the product as well as the e-commerce sale as shown in Table 12.

Table 12 — Activity of sales management for evaluation

Activity	Description
Demand forecasting	Use of IT systems and applications for supporting integrated demand forecasting with other system such as enterprise resource planning (ERP), manufacturing execution system (MES), product lifecycle management (PLM) and supply chain management (SCM), and its analysis
Delivery to promise	Use of IT systems and applications for delivery promise in conjunction with production plan
Order management	Use of IT systems and applications for managing order and strategic decision making based on contract information and cost information
Shipment management	Use of IT systems and applications for supporting shipment management and its optimization

6.2.2.6 Financial management

Financial management should be evaluated in terms of accounting management, capital management, accounting statement and analysis, cost management and financial budgeting management as shown in Table 13.

Table 13 — Activity of financial management for evaluation

Activity	Description
Budget management	Use of IT systems and applications for budget management and its optimization
Accounting management	Use of IT systems and applications for accounting management and its optimization

6.2.2.7 Security management

Security management should be evaluated in terms of information technology construction and application of security management, emergency response for the forecast and early warning about major sources of hazard as shown in Table 14.

Table 14 — Activity of security management for evaluation

Activity	Description
Physical protection and regulation management	Use of IT systems and applications for physical protection and regulation management
Risk management	Use of IT systems and applications for risk management
Infringement response management	Use of IT systems and applications for infringement response management

6.2.2.8 Project management

Project management should be evaluated in terms of research and manufacturing of product, project planning, project design, etc as shown in Table 15.

Table 15 — Activity of project management for evaluation

Activity	Description
Project management	Use of IT systems and applications for project management including analysis of project performance and prediction of future plans

6.2.2.9 Maintenance management

Maintenance management should be evaluated in terms of management of the equipment maintenance using IT as shown in Table 16.

Table 16 — Activity of maintenance management for evaluation

Activity	Description
Equipment maintenance	Use of IT systems and applications for supporting equipment maintenance including monitoring, preventive maintenance, automatic update of facilities, etc
Jigs and tools management	Use of IT systems and applications for managing jigs and tools for support of locating and customizing design of jigs and tool
Spare parts management	Use of IT systems and applications for managing spare parts supporting locating, lifetime management and guaranteeing safety stock of spare parts
Mould management	Use of IT systems and applications for mould management providing monitoring, locating and lifetime management, etc

6.2.2.10 Human resource management

Human resource management should be evaluated in terms of management of human resource planning and recruiting, training and development of the human resources, emoluments, benefits, achievement and employee relationship as shown in Table 17.

Table 17 — Activity of human resource management for evaluation

Activity	Description
Human information management	Use of IT systems and applications for promotion, and supporting of collaboration of personnel, etc

Table 17 *(continued)*

Activity	Description
Payroll management	Use of IT systems and applications for payroll management
Performance management	Use of IT systems and applications for managing the performance of personnel
Competency management	Use of IT systems and applications for competency management such as qualification evaluation and training, etc
Recruiting management	Use of IT systems and applications for supporting recruit and its management

6.2.2.11 Document management

Document management should be evaluated in terms of management of the documents collected from the enterprise as shown in Table 18.

Table 18 — Activity of document management for evaluation

Activity	Description
Document management	Use of IT systems and applications for managing the documents

6.2.2.12 Quality management

Quality management should be evaluated in terms of assurance of proper product quality as shown in Table 19.

Table 19 — Activity of quality management for evaluation

Activity	Description
Inspection and quality analysis	Use of IT systems and applications to support inspection and quality analysis
Experiment management	Use of IT systems and applications to manage experiment such as experimental data management and experimental data association with the real time in-house system

6.2.2.13 Environment, Health and Safety (EHS) management

EHS management should be evaluated in terms of providing healthy, safe and sustainable manufacturing environments as shown in Table 20.

Table 20 — Activity of EHS management for evaluation

Activity	Description
Environment management	Use of IT systems and applications to manage environment information and control environmental risks, etc
Health management	Use of IT systems and applications to manage employees' health data
Safety management	Use of IT systems and applications to support safety management

6.2.2.14 Energy management

Energy management should be evaluated in terms of assuring low energy consumption as shown in Table 21.

Table 21 — Activity of energy management for evaluation

Activity	Description
Energy-saving management	Use of IT systems and applications to manage energy consumption

6.2.3 Comprehensive integration aspect assessment

6.2.3.1 Product design and manufacturing integration

Product design and manufacturing integration should be evaluated in terms of the bidirectional flow of information between research and design, and manufacturing of product, such as data definition, data exchange and management of product specification as shown in Table 22.

Table 22 — Activity of product design and manufacturing integration for evaluation

Activity	Description
Exchange of process information between design and production	Use of IT systems and applications to exchange and integrate information between design process and production process
Exchange of material information between design and production	Use of IT systems and applications to exchange and integration information of material between design process and production process

6.2.3.2 Production management and control integration

Production management and control integration should be evaluated in terms of the integration between operation management, manufacturing execution of the plant and process control of the manufacturing enterprises as shown in Table 23.

Table 23 — Activity of production management and control integration for evaluation

Activity	Description
Routing management and dispatching	Use of IT systems and applications to support routing management and dispatching
Recipe management	Use of IT systems and applications to manage recipe supporting item-specific process or facility control
Resource allocation	Use of IT systems and applications to allocate manufacturing resources and its optimization

6.2.3.3 Production, supply and marketing integration

Production, supply and marketing integration should be evaluated in terms of the integration of production, supply and marketing such as production according to the order, optimization of production arrangement and dynamic scheduling, integrated operation of the supply chains and the traceability on the entire process of product quality as shown in Table 24.

Table 24 — Activity of production, supply and marketing integration for evaluation

Activity	Description
Logistics management	Use of IT systems and applications to support real time logistics information management
Sales management	Use of IT systems and applications to manage sales information and integrate it with production system

6.2.3.4 Operation decision support

Operation decision support should be evaluated in terms of the analysis of business information, knowledge mining and accumulation, business decision of the enterprises, building of the credibility of enterprises and risk management and control as shown in Table 25.

Table 25 — Activity of operation decision support for evaluation

Activity	Description
Decision support system management	Use of IT systems and applications to support decision making based on the real time analysis of company operation

6.2.4 Collaborative integration aspect assessment

Collaborative integration should be evaluated in terms of the convergence of information, resources, businesses and marketing between different enterprises as shown in Table 26.

Table 26 — Activity of collaborative integration for evaluation

Activity	Description
Planned-order collaboration (partner's perspective)	Use of IT systems and applications to support planned-order collaboration from partner's perspective, such as support of cooperation to guarantee delivery commitment based on customer's production plan in conjunction with all the customers' system
Procurement collaboration (customer's perspective)	Use of IT systems and applications to support procurement collaboration from customer's perspective such as checking the production status, process status, and logistics status of partner company in real time and manage the risks
Production collaboration (partner's perspective)	Use of IT systems and applications to support production collaboration from partner's perspective such as providing the customer with statistical process control (SPC) data acquired from the machinery and processes in real time
Development collaboration	Use of IT systems and applications to support development collaboration such as sharing and verifying the development information in stages and carrying out mass production approval

7 Guidance for maturity evaluation method

Stakeholders for maturity evaluation are enterprises that wish to assess their level of CII, therefore they shall answer to evaluation questionnaires.

Maturity evaluation shall be conducted by assessing the maturity of each activity of each component. The principle of assessment is to guide enterprises to assess the current situation of CII, to find the weakness, and to set up the milestone for improving CII.

The basic rule for assessment is that maturity evaluation shall be conducted on the activities of ACII reference model components resulting maturity level of the activities. This shall not derive any overall maturity level of each ACII reference model component, overall maturity level of four aspects and finally overall maturity level of an enterprise either.

However, it might be necessary to use a mechanism for averaging maturity level or weighing the importance of each activity to overall assessment. It is dependent on the situation of the enterprise conducting assessment, therefore this document does not define that kind of mechanism.

A maturity evaluation method is illustrated in Figure 3 and shall start at the Level 1 questions.

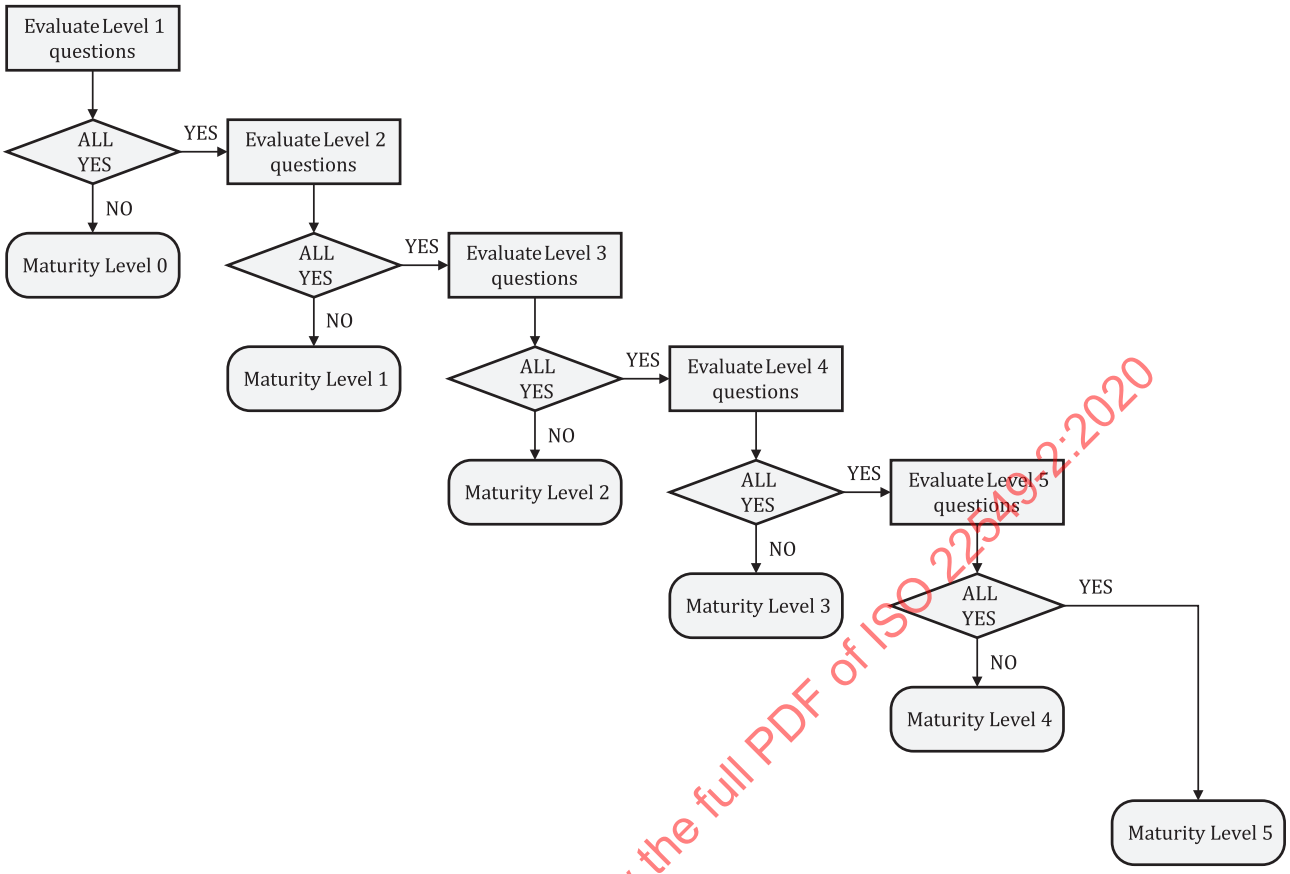

Figure 3 — Maturity level evaluation method

1) If all answers of the Level 1 questions are YES,
   - then shall proceed to the Level 2 questions
   - otherwise, maturity shall be Level 0
2) If all answers of the Level 2 questions are YES,
   - then shall proceed to the Level 3 questions
   - otherwise, maturity shall be Level 1
3) If all answers of the Level 3 questions are YES,
   - then shall proceed to the Level 4 questions
   - otherwise, maturity shall be Level 2
4) If all answers of the Level 4 questions are YES,
   - then shall proceed to the Level 5 questions
   - otherwise, maturity shall be Level 3
5) If all answers of the Level 5 questions are YES,
   - then maturity Level shall be 5
   - otherwise, maturity shall be Level 4

As described above, the principle of assessment is to guide an enterprise to assess the current situation of CII, to find the weakness, and to identify ways to improve CII. Therefore, it may be beneficial to visualize the result of evaluation. The use of spider charts is an appropriate means of displaying the relative maturity without mathematically manipulating the evaluation result.

Figure 4 illustrates an example of maturity evaluation result with a spider chart.

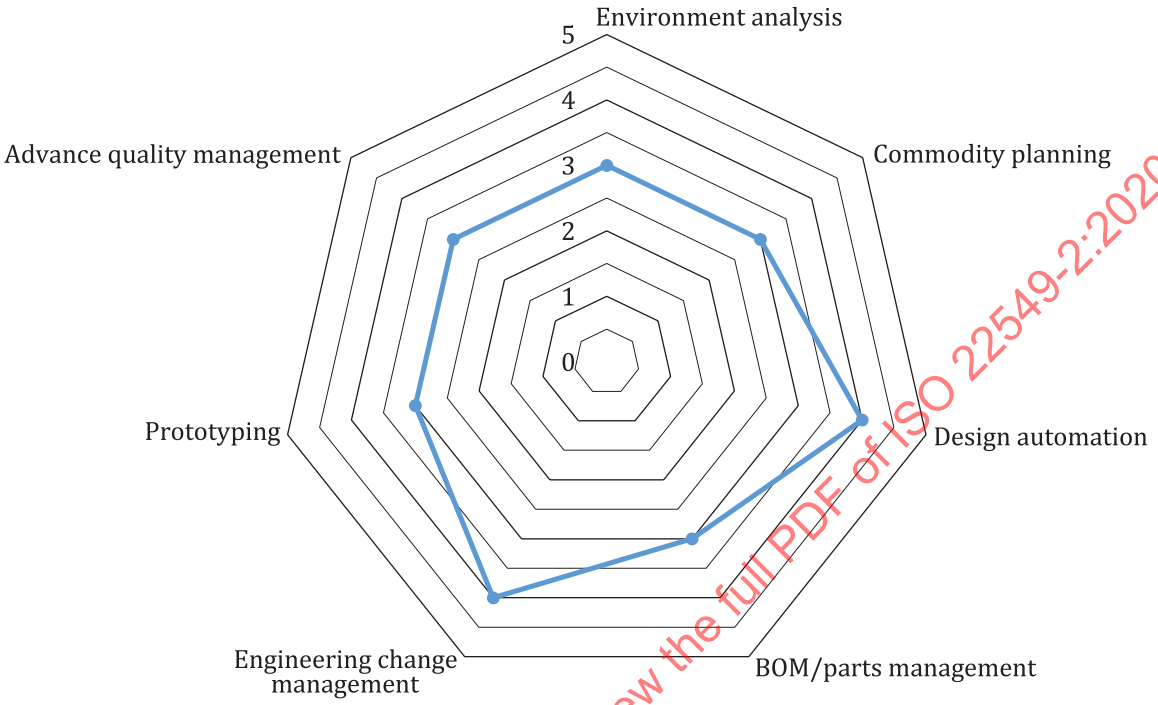

Figure 4 — EXAMPLE: Maturity evaluation on activities of production design component — strength

In Figure 4, it has a relatively high level of maturity in engineering change management and design automation.

On the other hand, Figure 5 illustrates an example of a relatively low level of maturity in recruiting management. Through this evaluation and visualizing the result, an assessing enterprise can easily find the weakness, and identify ways of improvement.

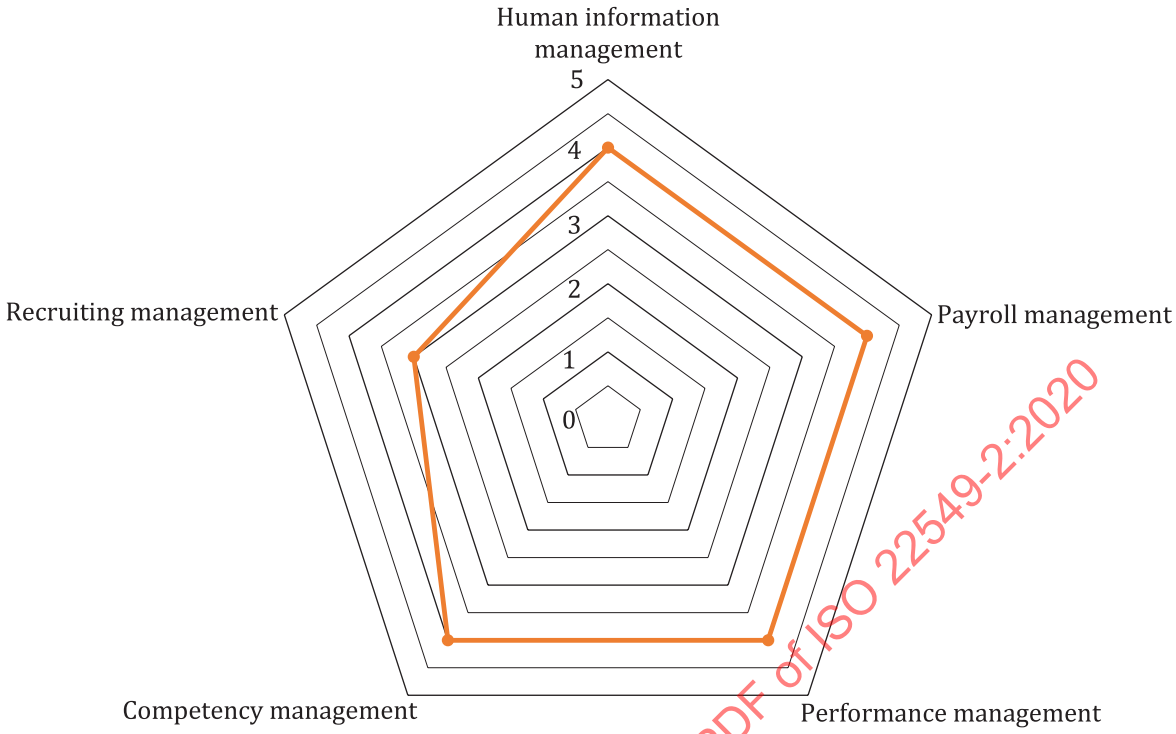

Figure 5 — EXAMPLE: Maturity evaluation on activities of human resource management component — weakness

Annex A
(informative)

Examples of evaluation questionnaires for ACII reference model components

A.1 Infrastructure aspect assessment

A.1.1 Capital investment

For evaluation of capital investment, questions in Table A.1 can be answered.

Table A.1 — Questions for assessment of capital investment

Activity	Questions	Maturity level indicator
Capital investment	— Do you invest in IT equipment? — Do you register the invested IT equipment to the systems?	1
	— Do you make an IT investment plan? — Do you carry out maturity Level 1 according to the plan?	2
	— Do you have a system to provide IT investment plan automatically?	3
	— Do you have a system to help investing IT equipment, for example, optimal time and prices?	4
	— Do you have a system for evaluating the performance against the IT investment plan and make improvements to the planning process?	5

A.1.2 Organization and planning

For evaluation of organization and planning, questions in Table A.2 can be answered.

Table A.2 — Questions for assessment of organization and planning

Activity	Questions	Maturity level indicator
Organization and planning	— Do you assign and register personnel when an IT job becomes available?	1
	— Do you establish IT job standards? — Do you assign and categorize personnel according to the standards?	2
	— Do you establish IT job standards with review and approval? — Do you establish a human resource growth roadmap with review and approval? — Do you place personnel according to the standards and the roadmap? — Do you circulate personnel to different roles according to the standards and the roadmap? — Do you train personnel according to the standards and the roadmap?	3
	— Do you evaluate the result of maturity Level 3?	4
	— Do you continuously improve the IT job standards? — Do you continuously improve the human resource growth roadmap? — Do you continuously improve the placement of personnel? — Do you continuously improve the circulation of personnel? — Do you continuously improve the training of personnel?	5

A.1.3 Equipment and facilities management

For evaluation of equipment and facilities, questions in Table A.3 can be answered.

Table A.3 — Questions for assessment of equipment and facilities management

Activity	Questions	Maturity level indicator
Equipment and facilities	— Do you have the documented processes in place to register IT HW and IT SW in an equipment master registry?	1
	— Do you make an inspection plan? — Do you execute the inspection plan?	2
	— Do you review the inspection plan? — Do you approve the inspection plan? — Do you execute the inspection plan?	3
	— Do you make a retirement and replacement plan? — Do you execute the retirement and replacement plan? — Do you evaluate IT H/W, IS S/W and related equipment?	4
	— Do you have a system in place for evaluating inspection and retirement and replacement plans and for making improvements to the plans?	5

A.1.4 Information resources management

For evaluation of information resources management, questions in Table A.4 can be answered.

Table A.4 — Questions for assessment of information resources

Activity	Questions	Maturity level indicator
Information resources	— Do you collect the necessary data from unit system, online, etc., for business use?	1
	— Do you standardize the collected data according to business rules to guarantee data quality for business use?	2
	— Do you accumulate the standardized data on both an event-by-event basis and time-driven basis for business use?	3
	— Do you have systems in place to provide useful information, present conclusions, and build and use decision support systems through inspecting, organizing, transforming, and modelling enterprise data?	4
	— Do you have a system in place to evaluate and improve management, standardization, and integration of information resources?	5

A.1.5 Information security management

For evaluation of information security management, questions in Table A.5 can be answered.

Table A.5 — Questions for assessment of information security management

Activity	Questions	Maturity level indicator
Computer and network security	— Do you manage the list of assets such as network, major asset list, configuration diagram, IP status?	1
	— Do you use access control according to services, user groups, information asset importance? — Do you have an intrusion prevention system according to services, user groups, information asset importance? — Do you conduct periodic inspections using server vulnerability analysis tools or security systems? — Do you operate anti-malware solutions mainly for business PCs?	2
	— Do you separate the network area logically? — Do you use access control using intrusion blocking system and VPN system? — Do you monitor the operation status of your wireless network and internal network assets? — Do you operate a vulnerability check tool or system? — Do you operate a malicious code prevention solution in important information systems? — Do you operate an automatic patching solution in important information systems?	3
	— Do you use access control using mobile network access control? — Do you operate a blocking system such as unauthorized wireless network? — Do you manage server vulnerability patch automation tool?	4
	— Do you operate an anomalous symptom monitoring system to detect abnormal conditions such as network connection of illegal terminals that occur during network operation? — Do you test the patches for system availability before automatic patching server vulnerabilities? — Do you operate a system to establish security measures in conjunction with analysis of anomalies by malicious code?	5

Table A.5 *(continued)*

Activity	Questions	Maturity level indicator
System and application security	— Do you set a password for a personal computer?	1
	— Do you have management systems for server, application, user account and access rights of the data base? — Do you operate a unit security solution such as password program mainly for personal business PC?	2
	— Do you monitor operating status of information system related assets such as hardware, operating system, commercial software package, etc? — Do you use cryptographic programs such as DB encryption systems to protect important data?	3
	— Do you have an associated system enforcing authentication other than password authentication separately? — Do you have an associated system monitoring the server, applications, and any anomalies that occur during database operation?	4
	— Do you use automated tools to manage information system assets such as hardware, operating system, commercial software packages, etc? — Do you measure the performance and security impact of asset changes? — Do you analyse the result of monitoring? — Do you apply the result of analysis to the establishment of the next security measures?	5

A.2 Domain application aspect assessment

A.2.1 Product design

For evaluation of product design, questions in Table A.6 can be answered.

Table A.6 — Questions for assessment of product design

Activity	Questions	Maturity level indicator
Design environment analysis	— Do you register information for product planning to the system, for example, markets, customers, and competitors?	1
	— Do you manually analyse the collected information? — Do you register the result to the system?	2
	— Do you analyse the collected information using specialized analysis tools, e.g., statistical analysis, etc?	3
	— Do you have a system that supports internal step-by-step process and reflects them in decision making based on the results of the environmental analysis?	4
	— Do you have a system that shares the latest product roadmaps and the latest technology roadmaps, and maintains the relationship between the two roadmaps?	5

Table A.6 *(continued)*

Activity	Questions	Maturity level indicator
Product planning	— Do you register the requirements collected for product planning in the system?	1
	— Do you manage the collected requirements of product development systematically by a system? — Do you manage the requirements to be applied to the functions of actual products using specific techniques such as quality function deployment (QFD)?	2
	— Do you use the system to simulate and technically review (feasibility studies) the product development including product design, development feasibility of parts, functional arrangements, etc., and ease-of-use?	3
	— Do you have a system in which entire related parts of enterprise join and discuss for the feasibility studies, planning, and decision making of product development?	4
	— Do you plan a product considering not only ideas inside your company but also ideas outside your company, i.e. Open Innovation?	5
Design automation	— Do you design with 2D CAD?	1
	— If you design 3D products, do you design with 3D CAD?	2
	— Do you analyse and validate with CAE?	3
	— Do you design automatically with optimization solutions as one of following? — Model based Parametric design (template design: automatic generation of model by inputting product characteristics) — Engineering based Parametric design (optimal design with input of formula and analysis result) — Integrated parametric design (design considering subsequent processes such as production, logistics, and customer service for warranty, etc.).	4
	— Do you design a product by using smart connected technology such as IoT, AR and VR?	5
BOM/parts management	— Do you upload the E-BOM to the system?	1
	— Do you integrate the E-BOM with 3D CAD? — Do you generate the E-BOM automatically?	2
	— Do you generate the M-BOM automatically in PLM? — Do you manage the software configuration in PLM?	3
	— Do you configure the BOM according to the purpose of use such as procurement, process cost, production, and customer service for warranty, etc.?	4
	— Do you improve business through preliminary simulation using the BOM data according to the purpose of use?	5

Table A.6 *(continued)*

Activity	Questions	Maturity level indicator
Engineering change management	— Do you register the ECO files in the system? — Do you manage the ECO files in the system systematically?	1
	— Do you make the ECO using systems? — Do you track changes and improvements of the ECO?	2
	— Do you execute the ECR using systems? — Do you manage the ECR in conjunction with the ECO?	3
	— Do you distribute the ECO to the post-process department (other system) systematically, e.g., ERP, MES, etc.?	4
	— Do you have a system that can systematically collect relevant department opinion and support decision making for impact analysis of engineering changes and deployment management?	5
Prototyping	— Do you register the results of prototyping in the system and manage them?	1
	— Do you maintain the BOM or material management system for prototyping?	2
	— Do you support digital test, quality prediction, and reliability prediction using digital mock-up (DMU) and digital pre-assembly (DPA)?	3
	— Do you have a systematic virtual assessment (validation) process? — Do you perform a virtual assessment to determine design specifications for each step?	4
	— Do you make overall workflow control? — Do you make integrated design by integration with the digital factory (virtual factory)?	5

Table A.6 *(continued)*

Activity	Questions	Maturity level indicator
Advance quality management	— Do you register the pre-quality data at the development stage in the system? — Do you manage the registered pre-quality data?	1
	— Do you have a history management system for quality issues and perform pre-quality verification for each stage of development?	2
	— Do you have the definite assessment criteria for achievement including product characteristic, reliability, stability, mass production, and etc., per product development type and grade? — Do you have a process for approval of mass production? — Do you share approval specification for mass production through the system for use as a standard of company quality control such as import inspection, shipment inspection and service quality control?	3
	— Do you prevent the recurrence of the same issue by using a preventive management system such as failure modes and effects analysis (FMEA) during product development? — Do you have a system to track quality issues?	4
	— Do you have the development quality management systems such as advanced product quality planning (APQP) and design for manufacturing (DFM)? — Do you assess the quality management system by regular and occasional audits? — Do you update the quality management system continuously by evaluating the compliance with international standards through an independent agency?	5

A.2.2 Process design

For evaluation of process design, questions in Table A.7 can be answered.

Table A.7 — Questions for assessment of process design

Activity	Questions	Maturity level indicator
Process design	— Do you register library data or process design data in the system?	1
	— Do you design the process, production-line, and plant lay-out using classical tool such as CAD?	2
	— Do you have a system to change the process design according to the engineering change of product?	3
	— Do you design and validate process, production-line and plant lay-out using digital manufacturing solutions?	4
	— Do you monitor the operation of the process and the equipment using IoT, and change the process and the lay-out if necessary?	5

A.2.3 Production management

For evaluation of production management, questions in Table A.8 can be answered.

Table A.8 — Questions for assessment of production management

Activity	Questions	Maturity level indicator
Master production scheduling	— Do you register planned production quantities into the system?	1
	— Do you register planned production quantities, production facilities, processes, and work groups into the system?	2
	— Do you make a production plan by systems? — Do you analyse the load of the production plan?	3
	— Do you have advanced planning and scheduling (APS)?	4
	— Do you analyse what-if and make alternatives in real time?	5
WIP management	— Do you identify and quantify process-specific WIP using identification code?	1
	— Do you identify process-specific WIP and production history information using identification code?	2
	— Do you manage the yield of process-specific WIP using identification code?	3
	— Do you check the location of WIP and the post-process schedule in real time?	4
	— Do you have automatic system to input WIP into the process?	5
Monitoring and control	— Do you automatically store the actual production in order units and production lots?	1
	— Do you automatically store the corresponding equipment, processes, and worker data in order units and production lots?	2
	— Do you analyse the cause using the system if there is a difference relative to the plan?	3
	— Do you re-establish resource allocation and dispatching in real time based on the result of the cause analysis of the difference?	4
	— Do you use CPS for monitoring and control?	5
Process control	— Do you collect process information, i.e., start and end of work, through data collection devices, which supports lot-tracking of the major processes?	1
	— Do you automatically collect process information from equipment or process transfer equipment, for example, bogies, pallets, forklifts, wagons, etc.?	2
	— Do you automatically aggregate major process operating information and analyse it in real time?	3
	— Do you automatically control the process?	4
	— Do you have a flexible production system supported by automatic work change and work preparation considering the surrounding environment?	5

Table A.8 *(continued)*

Activity	Questions	Maturity level indicator
Process analysis and enhancement	— Do you register data collected from facilities and processes?	1
	— Do you semi-automatically collect data using bar-code, RFID, etc., from equipment and processes? — Do you automatically aggregate the collected data?	2
	— Do you automatically collect data from equipment and processes through data collection devices? — Do you analyse the collected data in real time using the system? — Do you automatically detect process anomalies such as material shortage, equipment abnormality, and quality abnormality? — Do you automatically generate alarm or stop production line?	3
	— Do you automatically detect process anomalies such as equipment abnormality and quality abnormality? — Do you automatically control processes? — Do you provide operation guide in real time using detected information?	4
	— Do you have systems in place to evaluate process anomalies and provide corrective and preventative actions to eliminate the source of future anomalies?	5

A.2.4 Materials management

For evaluation of material management and inventory management, questions in Table A.9 can be answered.

Table A.9 — Questions for assessment of material management and inventory management

Activity	Questions	Maturity level indicator
Material order	— Do you register and manage the order data in the system?	1
	— Do you have an inventory management module? — Do you manage safety inventory? — Do you manage reorder points in case of scarcity?	2
	— Do you automatically order the material?	3
	— Do you use BOM as product units to calculate the material requirements and the shortage quantities?	4
	— Do you plan monthly, weekly, or daily procurement in conjunction with information such as master production schedule (MPS), BOM and inventory status? — Do you make purchase order (PO) and delivery order (DO) based on the procurement plan, or do you have vendor management inventory (VMI)?	5

Table A.9 *(continued)*

Activity	Questions	Maturity level indicator
Material receipt	— Do you register the material information when receiving the material?	1
	— Do you register material information with the data collection device when receiving the material?	2
	— Do you automatically collect data on materials, worker, and time on material receipt in the systems?	3
	— Do you identify the location of material in real time in the system when receiving material?	4
	— Do you automatically transfer the system-specified goods receipt location of received material to the transfer equipment or personnel?	5
Warehouse management	— Do you manage the quantity of materials in physical and logical warehouses?	1
	— Do you always monitor the properties of the material in the warehouse, such as its location and status?	2
	— Do you operate process such as first-in-first-out (FIFO) and last-in-first-out (LIFO) to minimize material loss by system?	3
	— Do you analyse data to optimize loading or aging?	4
	— Do you automate the aging optimization by considering automatically identified material properties or loading optimization through material relocation?	5
Weighing management	— Do you register the material weighing data to the system when releasing the material?	1
	— Do you automatically register weighing values when releasing the material?	2
	— Do you monitor the weighing data by system in real time, and send alarm with problem messages by system when problems occur?	3
	— Do you automatically control the weighing?	4
	— Do you analyse the cause and calibrate automatically by system when problems occur?	5
Material release and process input	— Does the worker reflect the inventory quantity in the system after material dispensing and the process input?	1
	— Do you automatically reflect the inventory quantity as soon as the materials are dispensed from warehouse?	2
	Do you automatically reflect process and WIP information immediately after the materials are dispensed from warehouse or put into the process?	3
	— Do you determine the appropriateness of the destination using information such as scheduler? — Do you issue alarm message in the event of an error in the destination?	4
	— Do you automate destination reflections and material dispatches according to the production control system?	5

A.2.5 Sales management

For evaluation of sales management, questions in Table A.10 can be answered.

Table A.10 — Questions for assessment of sales management

Activity	Questions	Maturity level indicator
Demand forecasting	— Do you register the demand history in the system and manage it?	1
	— Do you register the demand data in the system and forecast the demand with basic algorithms?	2
	— Do you forecast and analyse the demand using the system based on intelligent IT?	3
	— Do you collect and analyse the actual performance information required for the demand forecasting by linking with ERP, MES, PLM, and SCM? — Do you forecast and analyse the demand using the demand data based on intelligent IT?	4
	— Do you forecast the demand through specialized algorithms and crowdsourcing? — Do you use the forecasted demand to develop new products?	5
Delivery to promise	— Do you accept customer's demand on delivery without checking information when receiving an order?	1
	— Do you accept the order after on-site checking the product inventory by information system when receiving an order?	2
	— Do you accept the order whether that can be delivered from the product inventory using the system when receiving an order?	3
	— Do you make conjunction of the production plans with the order and provide delivery information when receiving an order?	4
	— Do you flexibly respond to the change of order of parent company? — Do you automatically establish production plan? — Do you provide delivery information?	5
Order management	— Do you register the estimated data and the order data in the system and track order history?	1
	— Do you use the system to manage production progress by order?	2
	— Do you manage contract information? — Do you analyse order fulfilment satisfaction?	3
	— Do you periodically analyse contract information? — Do you provide information in comparison with product cost?	4
	— Do you provide strategic decision making information by comparing the information of the contract, cost information, and management index information?	5

Table A.10 *(continued)*

Activity	Questions	Maturity level indicator
Shipment management	— Do you process shipments using data collection devices? — Do you make digital shipping instructions? — Do you keep track of product orders with stored data?	1
	— Do you automatically collect the shipment history using the system in conjunction with equipment and devices used in the shipping process?	2
	— Do you automate shipments ordered by the system in conjunction with the shipping equipment for packaging, labelling, shipping, etc.?	3
	— Do you automatically manage information about the distribution process of the shipped products, and use it for returning or collecting products?	4
	— Do you provide optimal flow information by analysing routing information for manufacturing and distribution logistics?	5

A.2.6 Financial management

For evaluation of financial management, questions in Table A.11 can be answered.

Table A.11 — Questions for assessment of financial management

Activity	Questions	Maturity level indicator
Budget management	— Do you identify and manage the finance-oriented factory budget plan including the amount of production and sales using the systems?	1
	— Do you measure and manage budget plans that reflect plant operation indicators such as quality, procurement, production, human resources, and informatization?	2
	— Do you operate and informatize the factory by the budget plan? — Do you periodically review the analysed results through the system?	3
	— Do you have the optimized factory budget information system to reflect the changing operating environment and share in a timely manner?	4
	— Do you make it possible to collaborate in real time by integrating and managing budget information with other tasks and other systems?	5

Table A.11 *(continued)*

Activity	Questions	Maturity level indicator
Accounting management	— Do you register the basic accounting management such as basic document processing, bond, financial obligation, financing, and settlement of accounts?	1
	— Do you automate statement analysis and cost management by linking purchasing, sales, bonds, and financial obligation with factory logistics information?	2
	— Do you have depreciation analysis simulation capability, and make departmental budgets, and control and manage expenses according to the budget?	3
	— Do you have total accounting management by the system, and collect and analyse data in real time?	4
	— Do you make it possible to collaborate in real time by integrating and managing accounting information with other tasks and other systems?	5

A.2.7 Security management

For evaluation of security management, questions in Table A.12 can be answered.

Table A.12 — Questions for assessment of security management

Activity	Questions	Maturity level indicator
Physical protection and regulation management	— Do you establish information protection regulations? — Do you operate physical protection zones to protect information systems?	1
	— Do you have access control to the physical protected area? — Do you have an information protection organization?	2
	— Do you have import and export management system for equipment in the physical protected area operated by a department dedicated to information security?	3
	— Do you operate the system for controlling the use of equipment, such as control of internal network use of portable storage media, in a physical protected area, and monitoring whether equipment in and out of the area is controlled?	4
	— Do you evaluate the performance of the implementation of physical protection measures, such as control of equipment use in physical protection areas, whether or not the control systems are being implemented, and reflect them in the next protection activities and measures?	5

Table A.12 *(continued)*

Activity	Questions	Maturity level indicator
Risk management	— Do you designate the person(s) who handles important information assets (information, systems, etc.) within the organization and clearly specify the roles/responsibilities?	1
	— Do you plan and implement on a regular basis information assets risk management?	2
	— Do you regularly check for technical risks by using inspection tools to check for vulnerabilities in information assets?	3
	— Using the information asset management system, — Do you systematically manage information assets? — Do you calculate the risk of information asset risk? — Do you establish a plan for implementation of information protection measures including processing strategies? — Do you have the security officer to report the results?	4
	— Using the information asset management system, — Do you manage information asset status in real time? — Do you conduct internal audits on the appropriateness and implementation of the information security measures implementation plan for information assets risk?	5
Infringement response management	— Do you create an information system operation log?	1
	— Do you operate a backup system for the information system operation log? — Do you check whether the information is infringing by checking the operation log in the important information system?	2
	— Do you use operational log analysis tools to analyse operational logs such as user access logs?	3
	— Do you have a monitoring system that is used to detect the occurrence of an infringement accident or anomalous signatures from the central office to the enterprise along with the use of automated log analysis tools such as user log records?	4
	Do you operate a system in conjunction with abnormal symptom detection and response systems to recognize and respond to intrusion attempts from outside in real time? — Do you operate it in conjunction with an external vulnerability providing system to periodically update information system vulnerability information?	5

A.2.8 Project management

For evaluation of project management, questions in Table A.13 can be answered.

Table A.13 — Questions for assessment of project management

Activity	Questions	Maturity level indicator
Project management	— Do you manage the schedule and the output which are the minimum management targets of the project in the system?	1
	— Do you maintain standard work breakdown structure (WBS) for each type and use required tasks, time period, and resources as basic data for planning? — Do you manage development planning and goal management in the system?	2
	— Do you manage the project's critical path? — Do you have a system that can manage all areas such as issues, resources, costs, and quality?	3
	— Do you have a system to retrieve all the information of the project in real time, and make decisions based on data in the system without manual report?	4
	— Do you have a system to analyse project performance and use the results to predict future project plans?	5

A.2.9 Maintenance management

For evaluation of maintenance management, questions in Table A.14 can be answered.

Table A.14 — Questions for assessment of maintenance management

Activity	Questions	Maturity level indicator
Equipment maintenance	— Do you register inspection information by data acquisition device and manage the repair and inspection history?	1
	— Do you operate on the master data on downtime? — Do you collect the downtime details by data acquisition device? — Do you have overall equipment effectiveness (OEE) indicator as the result?	2
	— Do you automatically aggregate downtime data and perform preventive maintenance based on the collected data and manage the maintenance history?	3
	— Do you monitor the condition of the facility by real time monitoring? — Do you use the information to manage the parts life and preventive maintenance plan to maintain the equipment?	4
	— Do you automatically update the facility information? — Does the facility diagnose by itself to forecast the downtime?	5

Table A.14 *(continued)*

Activity	Questions	Maturity level indicator
Jigs and tools management	— Do you manage the jigs and tools information in the system?	1
	— Do you manage the stock of jigs and tools by identification technologies such bar code and RFID as well as key-in?	2
	— Do you have the master data of jigs and tools, and analyse the history of use of jigs and tools?	3
	— Do you manage the location information through identifiers of jigs and tools, and location map?	4
	— Do you provide Big Data of the design area for customized design of jigs and tools?	5
Spare parts management	— Do you have the information of spare parts in the system? — Do you manage the stock of spare parts identification technologies such bar code and RFID as well as key-in?	1
	— Do you have the master data of spare parts? — Do you manage the life span through history management of usage?	2
	— Do you automatically calculate the periodic required amount based on the life span information of spare parts?	3
	— Do you manage the location information through identifiers of spare parts, and location map?	4
	— Do you make automatic ordering in conjunction with partner companies to secure safety stock of spare parts?	5
Mould management	— Do you manage the stock of mould by identification technologies such bar code and RFID as well as key-in, including management of outsourcing order?	1
	— Do you have the master data of moulds? — Do you manage the history including the repair and modification history in the system?	2
	— Do you automatically monitor the status of moulds, e.g., temperature, pressure, etc., by using various sensors combined with communication?	3
	— Do you automatically identify and locate the moulds using identification technologies? — Do you automatically calculate the mould ratio mould shot and put it into the system?	4
	— Do you predict the life of the moulds by aggregating operation information associated with the operation status of the equipment in real time? — Do you automatically compile the number of repair workers and manage the history of quality of moulds in the beginning, the middle, and the finish of work?	5

A.2.10 Human resource management

For evaluation of human resource management, questions in Table A.15 can be answered.

Table A.15 — Questions for assessment of human resource management

Activity	Questions	Maturity level indicator
Human information management	— Do you identify and manage personnel recruitment cards such as personal recruitment, human resource (HR) master, issuance, training, and benefits?	1
	— Do you automatically manage time and attendance using the access card system?	2
	— Do you automatically analyse and adjust yearly, special promotion and reorganization based on automatically collected time and attendance information and personnel evaluation information?	3
	— Do you have a system for personnel management providing real time data collection and analysis?	4
	— Do you have real time collaboration based on personnel information management in conjunction with other tasks and other systems?	5
Payroll management	— Do you register and manage the master data of payroll management by using system?	1
	— Do you register the payroll table by grades, individual national pension, medical insurance, and employment insurance management information in the system, and manage it simply?	2
	— Do you automatically manage labour costs information including individual salary, bonus, retrospective, and year-end settlement information by support of accounting system?	3
	— Do you have a system for payroll management supporting real time data collection and analysis?	4
	— Do you have real time collaboration based on payroll management in conjunction with other tasks and other systems?	5
Performance management	— Do you register and manage the master data of worker's performance management by using system?	1
	— Do you register performance information in the system according to basic personal evaluation criteria such as key performance indicator (KPI) and evaluation period, and simply identify and manage it?	2
	— Do you routinely measure and manage individual competency and performance?	3
	— Do you automatically analyse and manage KPIs by department and individual?	4
	— Do you have real time collaboration based on training management in conjunction with other tasks and other systems?	5

Table A.15 *(continued)*

Activity	Questions	Maturity level indicator
Competency management	— Do you register and manage the master data of worker's competency management by using system?	1
	— Do you have incomplete eligibility management, and register and manage the education plan information on the minimum duties and safety in the system?	2
	— Do you make employee competency development modelling, and manage eligibility, and establish job-oriented training programs?	3
	— Do you conduct periodic employee competency and qualification evaluations, and operate training programs focused on competency and eligibility?	4
	— Do you integrate employee competency and eligibility management with self-directed learning through work? — Do you automatically plan and operate employees' career development using the system?	5
Recruiting management	— Do you register and manage the master data of recruiting management by using system?	1
	— Do you manage recruiting documents and examination documents in the system?	2
	— Do you have a work system appropriate for recruiting? — Do you operate on-line system for job application support and examination?	3
	— Do you have a system for recruiting tasks providing various statistical functions for efficient operation of staffs and budget?	4
	— Do you have real time collaboration based on recruiting management information in conjunction with other tasks and other systems?	5

A.2.11 Document management

For evaluation of document management, questions in Table A.16 can be answered.

Table A.16 — Questions for assessment of document management

Activity	Questions	Maturity level indicator
Document management	— Do you register and manage major technical documents or materials such as technical specifications in the system?	1
	— Do you define the essential technical documents and register them in the system on a guarantee of effectiveness and up-to-date?	2
	— Do you have document security and rating management?	3
	— Do you manage various know-how as well as technical documents and other materials as assets of the company?	4
	— Do you accumulate data and do Big Data analysis?	5

A.2.12 Quality management

For evaluation of quality management, questions in Table A.17 can be answered.