Chapter 4
Maturity and Readiness Model for Industry 4.0 Strategy

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Abstract Companies that transform their businesses and operations regarding to Industry 4.0 principles face complex processes and high budgets due to dependent technologies that effect process inputs and outputs. In addition, since Industry 4.0 transformation creates a change in a business manner and value proposition, it becomes highly important concept that requires support of top management for the projects and investments. Therefore, it requires a broad perspective on the company's strategy, organization, operations and products. So, the maturity model is suitable for companies planning to transform their businesses and operations for Industry 4.0. It is a very important technique for Industry 4.0 in terms of companies seeking for assessing their processes, products and organizations and understanding their maturity level. In this chapter, existing maturity models for Industry 4.0 transformation are reviewed and a new Industry 4.0 maturity model is proposed.

4.1 Introduction

In today's world, economic challenges driven by technological and societal developments force industrial enterprises improve their agility and responsiveness in order to gain ability to manage whole value-chain. Hence, enterprises require assistance of virtual and physical technologies which provide collaboration and rapid adaption for their businesses and operations (Ganzarain and Errasti 2016). Implementation of Industry 4.0 strategies require wide applications in companies

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A. Ustundag and E. Cevikcan, *Industry 4.0: Managing The Digital Transformation*,
Springer Series in Advanced Manufacturing, https://doi.org/10.1007/978-3-319-57870-5_4

since executives from several industries are uncertain about outcomes of the Industry 4.0 projects and investment costs and they have lack of knowledge in the concept of Industry 4.0. Maturity models provide large scale of knowledge about companies' current state and a path to pursue for implementation of Industry 4.0 strategies.

Nikkhou et al. (2016) stated that maturity term refers to being in a perfect condition; also, it is an evidence of an achievement and it provides a guidance to correct or prevent problems. Mettler (2009) defined maturity as a development of a specific ability or reaching to a targeted success from an initial to an anticipated stage. Proença and Borbinha (2016) reported that maturity can be used as evaluation criteria and described as being complete, perfect or ready and also used for progression from a basic stage to more advanced final stage.

According to Tarhan et al. (2016) a maturity model represents desired logical path for processes in several business fields which include discrete levels of maturity. In addition, maturity models are defined as a valuable technique in order to assess processes or organization from different perspectives (Proença and Borbinha 2016). Backlund et al. (2014) also noted that maturity model frameworks are becoming extremely important to assess organizations. Nikkhou et al. (2016) described maturity models as a tool that can be used to describe perfect progression to wanted change utilizing a few progressive phases or levels. Maturity models enable organizations to audit and benchmark regarding to assessment results, to track progress towards to desired level and to evaluate elements of organizations such as strengths, weaknesses and opportunities by sequencing maturity levels in an order from basic to advanced stage: Initial, Managed, Defined, Quantitatively Managed and Optimizing (Proença and Borbinha 2016). According to Schumacher et al. (2016) maturity models are positioned as a tool for comparing current level of an organization or process to desired level in terms of maturity by conceptualizing and measuring. In the article, the difference between readiness and maturity models is explained in such a way that readiness models clarify whether organization is ready to start development process or not; however, maturity models target to demonstrate which maturity level the organization is in. In brief, Duffy (2001) concluded that maturity models help organizations to decide when and why they need to take an action to progress; in addition, teach organizations which actions should be considered in order to achieve advanced maturity level. According to author, organization must need the information obtained from maturity models to compare its current state to the best-practices in related business fields. Therefore, a value of a maturity model is measured by its usability on analysis and positioning.

In study of IBM in 2015, it is stated that Industry 4.0 transformation has many difficulties because of the inadequacy of current IT technologies, lack of knowledge and high investment costs (Erol et al. 2016). Digital transformation of companies' businesses and operations is driven by investments in information and telecommunication technologies and new machineries. In addition, the need of the integration in current technologies, new machines and automated work processes restrain horizontal and vertical integration along the value chain (Erol et al. 2016).

According to industry-wide interviews, when implementing Industry 4.0 in practice, following problems come in view (Schumacher et al. 2016):

- Lack of strategic guidance and the problem of perception about highly complex Industry 4.0 concept.
- Uncertainty about outcomes of Industry 4.0 projects in the matter of benefits and costs.
- Failure of assessing Industry 4.0 capability of company.

With regard to third problem, maturity models and assessment of Industry 4.0 maturity become highly important, since a lot of companies seem to struggle to initialize Industry 4.0 transformation.

The purpose of this chapter is to explain "maturity models"; discuss the encountered problems when implementing Industry 4.0 strategies; to explain reasons of utilization of these models and their benefits to Industry 4.0 strategies. The rest of the chapter is organized as follows. Section 4.2 includes detailed explanation of four maturity models in the literature. Then in Sect. 4.3, the comparison chart of analyzed Industry 4.0 maturity and readiness models is presented. Section 4.4 is organized to propose Industry 4.0 maturity model and an application in retail sector. The conclusion and future work are presented in final section.

4.2 Existing Industry 4.0 Maturity and Readiness Models

In this section, we performed analysis of several Industry 4.0 maturity and readiness models and assessment surveys. From these works, we derived concepts relevant for the structure of our model. Models and assessments are given below:

- IMPULS—Industrie 4.0 Readiness (2015)
- Industry 4.0/Digital Operations Self-Assessment (2016)
- The Connected Enterprise Maturity Model (2016)
- Industry 4.0 Maturity Model (2016).

4.2.1 IMPULS—Industrie 4.0 Readiness (2015)

Lichtblau et al. and other project partners performed Industry 4.0 workshops and literature researches to propose an Industry 4.0 readiness model. This model contains six levels of Industry 4.0 readiness given below:

- Level 0: Outsider
- Level 1: Beginner
- Level 2: Intermediate
- Level 3: Experienced

– Level 4: Expert
– Level 5: Top performer.

In this study, existing readiness model redesigned with contributions from workshops and formed in six Industry 4.0 dimensions by adding two dimensions to previous model. These dimensions (Lichtblau et al. 2015) are "Strategy and organization", "Smart factory", "Smart operations", "Smart products", "Data-driven services" and "Employees". Dimensions and associated fields of Industry 4.0 related with this model are given in Table 4.1.

Proposed readiness model is used in order to measure companies' Industry 4.0 readiness levels from 0 to 5 containing minimum requirements that companies should possess. Questionnaire of this readiness model measures structural characteristics of companies, their Industry 4.0 knowledge, their motivations and obstacles through Industry 4.0 journey. Assessment survey has 24 questions in total for related dimensions and a few questions about industry, size of domestic workforce and annual revenue. In order to measure and define Industry 4.0 readiness, five point Likert scale is used.

Company profiles are grouped under three titles to summarize results better (Lichtblau et al. 2015) such as Newcomers (level 0 and 1), Learners (level 2) and Leaders (level 3 and up). Newcomers consist of companies that have never initialized any projects or have studied a few projects. Learners consists a group of companies which initialized first projects related to Industry 4.0. Leaders is a group that contains level 3, 4 or 5 companies which are way ahead of other companies about Industry 4.0 implementation.

Companies' readiness levels are determined based on lowest level of associated field in the dimensions. Industry 4.0 dimensions are weighted on 100-point-scale. "Strategy and organization" has 25 point overall, "Smart factories" has 14 points

Table 4.1 Dimensions and associated fields of Industry 4.0 (Lichtblau et al. 2015)

Dimensions	Associated fields
Strategy and organization	Strategy Investments Innovation management
Smart factory	Digital modelling Equipment infrastructure Data usage IT systems
Smart operations	Cloud usage IT security Autonomous processes Information sharing
Smart products	Data analytics in usage phase ICT add-on functionalities
Data-driven services	Share of data used Share of revenues Data-driven services
Employees	Skill acquisition Employee skill sets

overall, "Smart products" has 19 points overall, "Data-Driven services" has 14 points overall, "Smart operations" has 10 points overall and finally "Employees" has 18 points overall.

As a result of measurements, company profiles are identified and main hurdles in the dimensions are listed. In the final stage, action plans are created for companies to help them reach level 5 Industry 4.0 readiness.

4.2.2 *Industry 4.0/Digital Operations Self-Assessment (2016)*

PwC published a report entitled "Industry 4.0: Building the digital enterprise" to provide companies comprehensive perspective on Industry 4.0 by representing its own maturity model and "Blueprint for Digital Success" given in Table 4.2.

In the first step of "Blueprint for Digital Success", PwC provides companies a maturity model to assess their capabilities. This maturity model is formed in four stages and seven dimensions. Stages are determined as below:

- Digital novice
- Vertical integrator
- Horizontal collaborator
- Digital champion.

PwC assess companies' maturity levels with seven dimensions such as "Digital business models and customer access", "Digitisation of product and service offerings", "Digitisation and integration of vertical and horizontal value chains", "Data and Analytics as core capability", "Agile IT architecture", "Compliance, security, legal and tax", "Organisation, employees and digital culture".

PwC enables companies to assess their Industry 4.0 maturity and map their results by online self-assessment tool. In the final stage of assessment, PwC provides companies an action plan to make them successfully reach high level of Industry 4.0 maturity.

Online self-assessment tool (PwC, 2016) has 33 questions in total for related dimensions and a few questions about industry, region, country and annual revenue to classify companies. In questionnaire, five point Likert scale is used for each question and radar graphic is provided at the end of the assessment.

Table 4.2 Blueprint for digital success (Geissbauer et al. 2016)

Practical steps					
Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Map out your Industry 4.0 strategy	Create initial pilot projects	Define the capabilities you need	Become a virtuoso in data analytics	Transform into a digital enterprise	Actively plan an ecosystem approach

4.2.3 The Connected Enterprise Maturity Model (2016)

The Connected Enterprise Maturity Model was developed by Rockwell Automation in 2014 and this model contains five stages and four technology focused dimensions. Stages in this model are given below (Rockwell Automation 2016):

- Stage 1: Assessment
- Stage 2: Secure and upgraded network and controls
- Stage 3: Defined and organized working data capital
- Stage 4: Analytics
- Stage 5: Collaboration.

The Assessment Stage of the Connected Enterprise Maturity Model evaluates all facets of an organization's existing OT/IT (Operational Technologies/Information Technologies) network with four dimensions such as "Information infrastructure (hardware and software)", "Controls and devices (sensors, actuators, motor controls, switches, etc.) that feed and receive data", "Networks that move all of this information" and "Security policies (understanding, organization, enforcement)". It is stated that a major challenge during assessment stage is potential hesitations on investing time for questioning practices that they have relied upon for years.

In Stage 2, OT/IT organization is being formed to deliver secure, adaptable connectivity between plant-floor operations and enterprise business systems after an assessment stage. Long-term upgrades begin and gaps and weaknesses of current operations are identified. In large-scale companies, outdated control and networks create a challenge for transformation as well as hesitations from executives and engineers who feel that current systems remain viable.

Stage 3, which the improvements made with the current data is in progress with Stage 2. At this stage, it is defined how the collected data will be processed and how to obtain optimum outcome from these data. Organized team ensures that new workflows, charts and responsibilities are set so that they are not overwhelmed by the company data pool thanks to Working Data Capital.

In Stage 4, focal point shifts towards continuous development with data. Analytics utilizing Working Data Capital will assist to pinpoint the greatest needs for real-time information and ensure the continuity of standardized protocols triggered by the data. In addition, these analytics provide information transfer about asset management for leadership team. Challenges during Stage 4 will be use of lots of unnecessary data and distrust of analytics.

In Stage 5, main idea is to provide collaboration between company and environment with the help of analytics and data sharing.

4.2.4 Industry 4.0 Maturity Model (2016)

Schumacher et al. (2016) used nine dimensions and sixty-two maturity items in order to assess companies Industry 4.0 maturity levels. Nine dimensions and maturity items are given in Table 4.3. Maturity levels are examined under five levels. According to this model, level 1 companies have lack of attributes the supporting concepts of Industry 4.0 and level 5 companies can meet all requirements of Industry 4.0.

In this maturity model, assessment surveys are made by using five point Likert scale for each closed ended question. After survey results weighted points are calculated and maturity levels of companies are determined. To determine maturity level of a company, an equation (Eq. 4.1) is used. In this equation, "M" corresponds to "Maturity", "D" corresponds to "Dimension", "I" corresponds to "Item", "g" corresponds to "Weighting Factor" and "n" corresponds to "Number of Maturity Item" (Schumacher et al. 2016).

$$M_D = \frac{\sum_{i=1}^{n} M_{DIi} * g_{DIi}}{\sum_{i=1}^{n} g_{DIi}} \tag{4.1}$$

Table 4.3 Dimensions and maturity items of Industry 4.0 Maturity Model (Schumacher et al. 2016)

Dimensions	Exemplary maturity item
Strategy	Implementation I40 (Industry 4.0) roadmap, Available resources for realization, Adaption of business models, …
Leadership	Willingness of leaders, Management competences and methods, Existence of central coordination for I40, …
Customers	Utilization of customer data, Digitalization of sales/services, Costumer's Digital media competence, …
Products	Individualization of products, Digitalization of products, Product integration into other systems, …
Operations	Decentralization of processes, Modelling and simulation, Interdisciplinary, interdepartmental collaboration, …
Culture	Knowledge sharing, Open-innovation and cross company collaboration, value of ICT in company, …
People	ICT competences of employees, openness of employees to new technology, autonomy of employees, …
Governance	Labour regulations for I40, Suitability of technological standards, Protection of intellectual property, …
Technology	Existence of modern ICT, Utilization of mobile devices, Utilization of machine-to-machine communication, …

4.3 Comparison of Existing Industry 4.0 Maturity and Readiness Models

In this section, maturity/readiness levels, dimensions and industry scope are compared between existing Industry 4.0 maturity and readiness models. In order to provide easy understanding, comparison table is given in Table 4.4.

4.4 Proposed Industry 4.0 Maturity Model

In order to facilitate different analyses of Industry 4.0 maturity, the proposed model includes a total of 13 associated fields which are grouped into 3 dimensions. Table 4.5 provides an overview on the dimensions together associated fields, related Industry 4.0 to support understanding. An assessment criterion of the maturity model is based on Industry 4.0 principles and technologies given in Table 4.6 for each associated field.

Smart products can do computations, store data and be involved in an interaction with their environment as well as they can give information about their identity, properties, status and history (Schmidt et al. 2015). These features create a chance to obtain data from products and interpret data to offer services. **Smart Products**

Table 4.4 Comparison of existing industry 4.0 maturity and readiness models

Maturity/readiness model	Maturity/readiness levels and dimensions	Industry scope
IMPULS—Industrie 4.0 Readiness (2015)	5-staged readiness model with 6 dimensions and 18 criteria. Development steps for each stage are clearly defined. Main hurdles, obstacles and action plans are determined for each stage	Focused on manufacturing and engineering industry. Limited application area
Industry 4.0/Digital operations self-assessment (2016)	4-staged maturity model with 7 dimensions. Undefined maturity criteria. Comments and short action plans are provided as a result of online assessment	Industry wide maturity model. Wide application area
The connected enterprise maturity model (2016)	5-staged maturity models with 5 dimensions and technology focus. Undefined maturity criteria. Lack of assessment tool	Focused on IT capability of companies. Lack of organization and operations dimension. Limited application area
Industry 4.0 Maturity Model (2016)	5-staged maturity model with 9 dimensions and 62 maturity items. Basic formulation for assessment	Focused on manufacturing industry. Comprehensive maturity model and assessment. Limited application area

Table 4.5 Proposed industry 4.0 maturity model

Dimensions	Sub-dimension	Associated fields
Smart products and services		Smart products and services
Smart business processes	Smart production and operations	Production, logistics and procurement
		R&D—Product development
	Smart marketing and Sales operations	After sales service
		Pricing/Promotion
		Sales and Distribution channels
	Supportive operations	Human resources
		Information technologies
		Smart finance
Strategy and Organization		Business models
		Strategic partnerships
		Technology investments
		Organizational structure and leadership

and Services dimension is formed to measure these features of companies' products and their service offerings driven by product data.

Smart Business Processes is formed as a dimension containing functional operations of companies to assess their maturity level regarding to Industry 4.0 principles and triggering technologies.

Strategy and Organization can be defined as an "input" for Industry 4.0 transformation where it is important to shape business and organization. Development of new smart products, data-driven services and smart business operations depend on generating suitable business models or transforming current one for Industry 4.0, investments in triggering technologies, collaboration with strategic partners which provides fast progression and organizational structure and leadership.

To identify Industry 4.0 maturity level of a company, four stages are used and answers of the assessment survey is evaluated regarding to these stages such as "Absence", "Existence", "Survival" and "Maturity". Each associated field's questions weighted between 0—"Absence" and 3—"Maturity" to determine a maturity level.

Level 0: Absence identifies a level of a company that does not meet any of the requirements for Industry 4.0. Some of the requirements are at low level.

Level 1: Existence is a maturity level where company has some pilot initiatives in its functional departments. Company provides products, but these products are not capable of being fully smart. Integration and automation levels are low and data collection/use levels are not enough to realize Industry 4.0 transformation. Digital technologies and cloud has not been implemented to all operations. Equipment infrastructure readiness is also at low level. Top management is considering implementing Industry 4.0 strategy with investments in a few areas. There are pilot initiatives to generate business models or transform current one. Organizational structure is not suitable enough.

Table 4.6 Industry 4.0 principles and technologies

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Interoperability Virtualization Decentralized Agility Service oriented Integrated business processes	Adaptive robotics Data analytics and Artificial intelligence Simulation Embedded systems Communication and Networking Cybersecurity Cloud Additive manufacturing Virtualization technologies Sensors and Actuators RFID and RTLS technologies Mobile technologies

Level 2: Survival is a maturity level where company's products are capable of real time data management and being tracked through different sites; in addition, data-driven service offerings are at medium level. Company's business processes at medium level in terms of integration, data sharing/collection/use and agility. Processes are ready for decentralization and interoperability principle is implemented a few areas in company with support of digital technologies. Leadership is developing plans for Industry 4.0 and has made investments in a few areas. Company is considering new business opportunities at medium level and creating partnerships with other companies or academics. Organizational structure is suitable for initial Industry 4.0 projects and new business models are being generated.

Level 3: Maturity is a maturity level where company's products are defined as smart and data-driven services are provided high level. Company's business processes at high level in terms of integration, data sharing/collection/use and agility. Nearly all processes are capable of being decentralized and interoperability principle is implemented lots of areas in company with support of advanced digital technologies. Leadership team provides widespread support for Industry 4.0 and has made investments for nearly all departments. Organizational structure is suitable for managing transformation across the company. Company is creating lots of partnerships with companies, academics, suppliers and technology providers. Digital business models are integrated to company's current business models and company is generating revenue from these models.

Each associated field in this maturity model is graded with related survey questions by 0–3 points. After all, calculated points of associated fields are grouped under dimensions and sub-dimensions in order to identify maturity levels individually and overall. Equations to calculate maturity levels are given in Eqs. 4.1–4.3.

M Maturity
D Dimension
A Associated Field
Q Question Number
O Overall

n Number of Total Questions
m Number of Associated Fields

$$M_{DAi} = \frac{\sum_{j=1}^{n} Q_{Aij}}{n} \tag{4.2}$$

$$M_D = \frac{\sum_{i=1}^{m} M_{DAi}}{m} \tag{4.3}$$

$$M_O = \min(M_1, M_2, M_3) \tag{4.4}$$

Table 4.7 Limit values to determine maturity level

	Limit values	
Maturity level	Low	High
Level 0: Absence	0.00	0.90
Level 1: Existence	0.90	1.80
Level 2: Survival	1.80	2.70
Level 3: Maturity	2.70	3.00

Table 4.8 Smart products and services maturity level requirements

Maturity level	Smart products and services
Level 0: Absence	Company does not meet any of the requirements for Industry 4.0. Some of the requirements are at low level
Level 1: Existence	Company's products are capable of communicating with other products/platforms, machines and external systems as well as collecting data Products can be tracked as they move between manufacturing and internal internal distribution sites Company offer service/insights for only its business according to data obtained from the product
Level 2: Survival	Company's products are capable of communicating and collecting data. In addition, products can keep data they collect on their system or in the cloud Product can perform descriptive, diagnostics and predictive data analysis. Products can be tracked as they move between manufacturing and distribution until they reach the customers DC Company offer service/insights for its business and customers according to data obtained from the product
Level 3: Maturity	Company's products are capable of communicating with other systems, collecting data and keeping it on their system or in the cloud. In addition, products have a platform on which the product or cloud applications are working Product can perform descriptive, diagnostics, predictive and prescriptive data analysis Products can be tracked along their complete lifecycle Company offer service/insights for its business, customers and partners according to data obtained from the product improvements

Table 4.9 Smart business processes maturity level requirements

Maturity level	Smart business processes
Level 0: Absence	Company does not meet any of the requirements for Industry 4.0. Some of the requirements are at low level
Level 1: Existence	Supply chain processes are integrated between company, suppliers and customers in terms of basic data sharing and communication There are a few software systems in use and production systems are partially automated at machine level. Operation process traceability is provided at machine level (partial) in the digital environment and end-to-end visibility is at low level as well as the production customization level. Data usage in new product development is at low level. Manufacturability and terms of use of the product is simulated during product development at low level In after sales services process, company benefits from few data and offer services in a few area. Triggering technologies (i.e. mobile and virtualization technologies, cloud) are not in use. A few analytics studies are conducted and data obtained from environment is not used in product pricing and dynamic pricing. Campaign systems and sales channels has low level integration and data analytics tools are not in use to measure campaign performances. Integration of communication channels and collaboration with partners are at low level. In Human Resources operations data is used in a few areas, but company does not share real-time data with field workers and e-learning is not an option. IT security solutions are planned or in progress for data through cloud services. IT dashboards are not in use and machines/systems can be controlled through IT to some extent. Automation of financial services is at low level and analysis generally basis on historical data. Triggering technologies (i.e. 3D printers, cloud, mobile and virtual technologies, etc.) are being used at low level
Level 2: Survival	Supply chain processes are integrated between company, and key strategic suppliers/customers in terms of data transfer. There are some software systems in use and production systems are exactly automated at machine level or partially automated at production line/cell level. Operation process traceability is provided at production line/cell level in the digital environment and end-to-end visibility is at medium level as well as the production customization level. Data usage in new product development is at medium level. Manufacturability and terms of use of the product is simulated during product development at medium level In after sales services process, company benefits from some data and offer services in areas. Triggering technologies (i.e. mobile and virtualization technologies, cloud) are in use. Analytics studies are conducted and data obtained from environment is used in product pricing and dynamic pricing. Campaign systems and sales channels has medium level integration and data analytics tools are in use to measure campaign performances. Integration of communication channels and collaboration with partners are at medium level. In Human Resources operations data is used in some areas, company shares real-time data with field workers and e-learning is an option. IT security solutions are in progress or implemented in terms of communications for in-house data exchange. IT dashboards are in use and machine to machine communications are available. Automation of financial services is at medium level and analysis generally basis on historical data. Triggering technologies (i.e. 3D printers, cloud, mobile and virtual technologies, etc.) are being used at medium level

(continued)

Table 4.9 (continued)

Maturity level	Smart business processes
Level 3: Maturity	Supply chain systems are fully integrated between company, suppliers and customers which provides real-time planning. There are lots of software systems in use and production systems are exactly automated at production line/cell level or partially automated in factory level. Operation process traceability is provided at factory level in the digital environment and end-to-end visibility is at high level as well as the production customization level. Data usage in new product development is at high level. Manufacturability and terms of use of the product is simulated during product development at high level. In after sales services process, company benefits from lots of data and offer services in wide range. Triggering technologies (i.e. mobile and virtualization technologies, cloud) are in use. Analytics studies are conducted and data obtained from environment is used in product pricing and dynamic pricing. Campaign systems and sales channels has high level integration and data analytics tools are in use to measure campaign performances. Integration of communication channels and collaboration with partners at high level. In Human Resources operations data is used in lots of areas, company shares real-time data with field workers and e-learning is an option. IT security solutions are implemented for data exchange with business partners. IT dashboards are in use and interoperability principle is applied completely. Automation of financial services is at high level and analysis generally basis on real-time data. Triggering technologies are being used at high level

Table 4.10 Strategy and organization maturity levels requirements

Maturity level	Strategy and organization
Level 0: Absence	Company does not meet any of the requirements for Industry 4.0. Some of the requirements are at low level
Level 1: Existence	Existing products and services are not compatible with digital business models which is supported with resources at low level There is an awareness of "as a service" business model and revenue is generated from data-driven services (0–2.5%) Company has partnerships with a few stakeholders and launched pilot initiatives. Leadership team is investigating potential benefits Company allocated low level of budget to technologies and is planning investments in a few functional operations; but cost/benefit analysis are not conducted Organizational structure is not suitable for transformation Only technology focused areas has employees with digital skills that are not allocated to specific Industry 4.0 projects Central IT departments are existed in the company where there is not any working environment where OT/IT units work together There is limited interaction between departments

(continued)

Table 4.10 (continued)

Maturity level	Strategy and organization
Level 2: Survival	Existing products and services are compatible with digital business models which is supported with resources at medium level There is a high awareness of "as a service" business model and revenue is generated from data-driven services (2.5–10%) Company has partnerships with some of stakeholders and strategy is formulated. Leadership team recognizes financial benefits and plans to invest Company allocated medium level of budget to technologies and investments are done in some of functional operations; in addition annual cost/benefit analysis are conducted Organizational structure is suitable for initial projects In most areas of the business have well developed digital skills that are allocated to specific Industry 4.0 projects in different units Local IT departments are existed in each area where there is a working environment where OT/IT units work together Departments are open to cross-company collaboration
Level 3: Maturity	Existing products and services are compatible with digital business models which is supported with resources at high level "As a service" has been implemented and is being offered. Revenue is generated from data-driven services (over 10%) Company has partnerships with lots of stakeholders and strategy is implemented or in implementation. Widespread support for the Industry 4.0 within leadership and across the wider business Company allocated high level of budget to technologies and invested in nearly all functional operations; in addition quarterly cost/benefit analysis are conducted Organization is well structured for transformation All across the business, cutting edge digital and analytical skills are prevalent and allocated to specific Industry 4.0 projects in same units IT experts attached to each department where there is a working environment where OT/IT units work together Departments are open to cross-company collaboration to drive improvements

To determine overall maturity level, limit values for each level is given in Table 4.7. Maturity levels of "smart products and services", "smart business" and "strategy and organization" are explained in Table 4.8, 4.9 and 4.10 respectively.

4.5 An Application in Retail Sector

The study was conducted in a retail company operating in Turkey. In this study, the questionnaires in Appendix were answered and according to the answers given, scores related to the relevant fields and dimensions were calculated according Eqs. 4.2–4.4.

Table 4.11 Smart products and services maturity score

	Score
# of question	Smart products and services
1	3.00
2	3.00
3	1.00
4	3.00
Maturity Score	2.50

Table 4.12 Smart business processes maturity score

	Score							
# of question	Production, Logistics and procurement	R&D—product development	After sales services	Pricing/ promotion	Sales and distribution channels	Human resources	Information technology	Smart finance
1	1.31	N/A	0.66	3.00	3.00	1.50	3.00	0.00
2	3.00	N/A	N/A	0.00	0.00	3.00	2.00	3.00
3	0.00	N/A	1.00	3.00	3.00	3.00	3.00	3.00
4	1.50	N/A		3.00	3.00		1.50	2.00
5	1.13	N/A		3.00	1.00			2.00
6	1.00				0.00			
7	0.60				0.00			
8	1.00							
9	0.00							
10	0.00							
Associated field score	0.95	N/A	0.83	2.40	1.43	2.50	2.38	2.00
Maturity score	1.60							

The scores corresponding to the answers given to the questions are shown on the Tables 4.11, 4.12 and 4.13. Since the firm operates in the retail sector, it has decided not to answer the questions about the field of "R&D—Product Development". So this field did not participate in the scoring account according to Eqs. 4.2–4.4.

According to an equation (Eq. 4.4), overall maturity level of a company is determined by minimum maturity level of dimensions. As we can see in Table 4.11, Table 4.12 and Table 4.13, minimum maturity level score is 1.14 which is calculated for Strategy and Organization dimension. Therefore, a retail company is at "Level 1: Existence" regarding to Industry 4.0 maturity. Summary of maturity scores is given in Table 4.14. Radar chart is provided in Fig. 4.1.

Table 4.13 Strategy and organization maturity score

	Score			
# of question	Business models	Strategic partnerships	Technology investments	Organizational structure and leadership
1	3.00	1.50	1.75	3.00
2	0.00	1.00	1.00	3.00
3	2.00	0.00	0.00	3.00
4	0.00		0.94	1.00
5	0.00			0.00
6				2.00
7				2.00
8				1.00
9				0.00
10				3.00
Associated field score	1.00	0.83	0.92	1.80
Maturity score	1.14			

Table 4.14 Maturity score and level table for each dimension/sub-dimension of a company

Dimension/Sub-dimension	Maturity level	Maturity score
Smart products and services	Level 2: Survival	2.50
Smart business processes	Level 1: Existence	1.60
Smart production and operations	Level 1: Existence	0.95
Smart marketing and sales operations	Level 1: Existence	1.55
Supportive operations	Level 2: Existence	2.29
Strategy and organization	Level 1: Existence	1.14

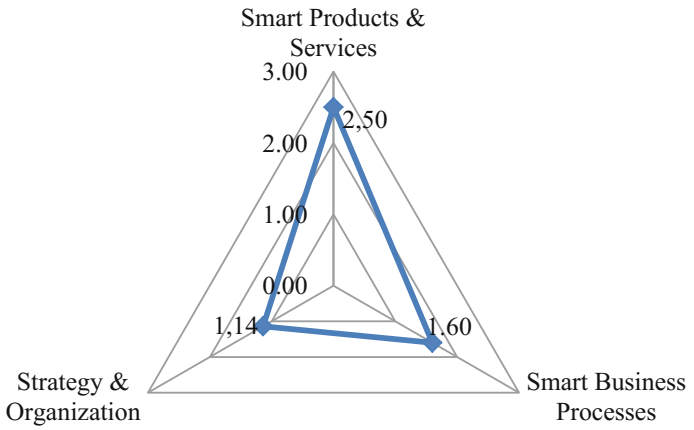

Fig. 4.1 Maturity levels of dimensions of company in a radar chart

4.6 Conclusion

The study presented here aimed to develop of an Industry 4.0 maturity model and an assessment survey to provide companies a tool to help them understand their current state regarding to Industry 4.0. Different application areas were proposed for Industry 4.0 such as smart finance, smart marketing and human resources in order to differentiate the model and increase companies' perspective for Industry 4.0 applications. Future studies will aim at diversifying Industry 4.0 maturity model to enhance the industry scope with weighted associated fields for each industry and create activity plans according to companies' current maturity level.

Appendix: Survey Questionnaire

Smart Products and Services

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Interoperability Decentralized Service oriented	Data analytics and Artificial intelligence Embedded systems Communication and Networking Cybersecurity Sensors and Actuators Cloud RFID and RTLS Technologies

Questionnaire

1. Which functions can your company's products fulfill the following options?

Communicating with other products/platforms, machines and external systems
Collecting data from environment and other systems
Keeping the data they collect on their system or in the cloud
Having a platform on which the product or cloud applications are working

2. What stages of the data analysis can the product perform? (Porter and Heppelmann 2015)

Descriptive—Capture products' condition, environment and operation
Diagnostic—Examine the causes of reduced product performance or failure
Predictive—Detect patterns that signal impending events
Prescriptive—Identify measures to improve outcomes or correct problems

3. To what extent can products be tracked throughout their lifecycle? (The University of Warwick Maturity Model)

No or limited product tracking
Products can be tracked as they move between manufacturing and internal distribution sites
Products can be tracked through manufacturing and distribution until they reach the customers DC
Products can be tracked along their complete lifecycle

4. Who do you offer service/insights for according to the user data obtained from the product?

None
Business
Customers
Partners

Smart Business Processes
Production, Logistics and Procurement

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Interoperability Virtualization Decentralized Agility Integrated business processes	Data analytics and Artificial Intelligence Adaptive robotics Simulation Communication and Networking Cybersecurity Additive manufacturing Virtualization technologies Sensors and Actuators Cloud RFID and RTLS Technologies Mobile Technologies

Questionnaire

1. Which of the following systems do you use? Does the system have an interface to the leading system? (Lichtblau et al. 2015)

	Interface to leading system	
	No	Yes
MES—manufacturing execution system		
ERP—enterprise resource planning		
PDM—product data management		
PPS—production planning system		
PDA—production data acquisition		
MDC—machine data collection		
CAD—computer-aided design		
SCM—supply chain management		

2. To what extent is the current supply chain integrated? (The University of Warwick Maturity Model)

Ad hoc reactive communication with suppliers and customers
Basic communication and data sharing where required with suppliers and customers
Data transfer between key strategic suppliers/customers (for example customer inventory levels)
Fully integrated systems with suppliers/customers for appropriate processes (for example real time integrated planning)

3. To what extent are the production equipment and systems automated?

Machine level: Partial
Machine level: Exact (Loading/Unloading + Operation)
Production line/cell level: Partial
Production line/cell level: Exact (Loading/Unloading + Operation +Transportation)
Factory level: Partial

4. Express the level of personalization in production.

Low—10,000 + batch size
Medium
High—1 batch size

5. Which data about your machinery, processes, and products as well as malfunctions and their causes is collected during production, and how is it collected? (Lichtblau et al. 2015)

	Manually	Automatically
Inventory data		
Manufacturing throughput times		
Equipment capacity utilization		
Production residues		
Error quota		
Employee utilization		
Data on remaining processing		
Overall equipment effectiveness (OEE)		
Other:		

6. How is the data you collect used in production? (Lichtblau et al. 2015)

Predictive maintenance
Optimization of logistics and production processes
Creation of transparency across production process
Quality management
Automatic production control through use of real-time data
Optimization of resource consumption (material, energy)
Other:

7. How is the data you collect used in logistics and procurement? (Schreiber et al. 2016)

Predictive supplier risk management (to detect supplier failures early on)
Digital supplier scorecards, objectives and improvement tracking.
Automated tracking of target achievement and bonus payments
Digital claim management system with integrated automatic warning system
Big data analytics to detect new suppliers globally

8. To what extent does your supply chain an end-to-end visibility? (The University of Warwick Maturity Model)

No integration with suppliers or customers
Site location, capacity, inventory and operations are visible between first tier suppliers and customers
Site location, capacity, inventory and operations are visible throughout supply chain
Site location, capacity, inventory and operations are visible in real time throughout supply chain and used for monitoring and optimization

9. What is the level of real-time traceability of the operation in the digital environment? (Digital-twin concept)

None
Machine level
Production line/cell level
Factory level

10. What is the use level of technologies in production, logistics and procurement?

	Mobile and virtual technologies	3D Printers	Adaptive and collaborative robots
None			
Low			
Medium			
High			

Smart Business Processes
R&D—Product Development

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Virtualization Agility	Data analytics and Artificial intelligence simulation communication and Networking Cybersecurity additive manufacturing virtualization technologies cloud RFID and RTLS technologies

Questionnaire

1. To what extent are the manufacturability and terms of use of the product simulated during product development?

None
Low
Medium
High

2. To what extent is the data obtained from the product used in the new product development?

None
Low
Medium
High

3. Do you use 3D printers in the production/prototyping processes?

No
Yes

4. Is product design information automatically transferred with the CAD/CAM systems to the machine?

No
Yes

5. Can your customers customize your products before production according to their preferences?

No
Yes

Smart Business Processes
After Sales Services

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Virtualization Agility Service oriented	Data analytics and Artificial intelligence Embedded systems Communication and Networking Cybersecurity Virtualization technologies Cloud RFID and RTLS technologies Mobile technologies

Questionnaire

1. How do you benefit from data you collect in after-sales services?

Early detection of product quality issues and focused recalls
Improved product design
Advanced supplier recovery
Optimized spare parts planning
Minimized suspect and fraudulent claims
Reduced “remorse returns” and no trouble found rates
Increased reserves forecast accuracy
Enhanced service quality and service information
Intensified customer intimacy and next best action

2. Which services do you provide by using data analytics and other technologies in after-sales services?

Remote maintenance
Assistance with problems or faults in real time
IT-assisted claim management
Order management (CRM, order history, delivery tracking, etc.)
Display of product history
Delivery forecast

3. Do you utilize from digital technologies (mobile and virtualization technologies) in after-sales service processes?

No
Yes

Smart Business Processes
Pricing/Promotion

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference)	Data analytics and Artificial intelligence
Decentralized	Communication and Networking
Service oriented	Cybersecurity
Integrated business processes	Cloud

Questionnaire

1. Which of the following studies are conducted within customer analytics?

Customer segmentation
Customer lifetime value
Cross selling
Campaign management
Market basket analysis/product bundling
Product recommendation
Customer churn analysis
Product portfolio management

2. Do you utilize from data obtained from environment/other platforms in product pricing or dynamic pricing?

	Product pricing	Dynamic pricing
No		
Yes		

3. Do you generate new campaigns from purchasing and product usage data?

No
Yes

4. Do campaign management systems work integrated with other systems?

No
Yes

5. Do you analyze campaign performance to use these analyses in new campaigns?

No
Yes

Smart Business Processes Sales and Distribution Channels

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Agility Service oriented	Data analytics and Artificial Intelligence Communication and Networking Cloud Mobile technologies

Questionnaire

1. What is the level of sales team support with digital products and services and real-time access to systems?

None
Low
Medium
High

2. Do you conduct real-time profitability analysis?

No
Yes

3. Do you use real-time and automated performance management systems for local sales force?

No
Yes

4. To what extent are your sales channels integrated?

None
Low
Medium
High

5. To what extent do you use integrated channels to communicate with customers and to manage customer interaction?

None
Low
Medium
High

6. To what extent do you collaborate with partners to reach customers (i.e. exchange of customer insight, etc.)?

None
Low
Medium
High

7. Which content analyses are performed on social media?

None
Sentiment analysis
Trend analysis

Smart Business Processes
Human Resources

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Agility	Data analytics and Artificial intelligence Cloud Mobile technologies

Questionnaire

1. In what areas is the data collected and data analytics is used?

	Data collected	Data analytics used
Capability analytics—(a talent management process that allows you to identify the capabilities or core competencies you want and need in your business.)		
Capacity analytics—(seeks to establish how operationally efficient people are in a business.)		
Competency acquisition analytics—(the process of assessing how well or otherwise your business acquires the desired competencies.)		
Employee churn analytics—(the process of assessing your staff turnover rates in an attempt to predict the future and reduce employee churn.)		
Corporate culture analysis—the process of assessing and understanding more about your corporate culture or the different cultures that exists across your organization.)		
Recruitment channel analytics—(the process of working out where your best employees come from and what recruitment channels are most effective.)		
Leadership analytics—(unpacks the various dimensions of leadership performance via data gained through the use of surveys, focus groups, employee interviews or ethnography.)		
Employee performance analytics—(seeks to assess individual employee performance.)		

2. Can your company share real-time data with employees in the field?

No
Yes

3. Can employee training be carried out in a virtual environment?

No
Yes

Smart Business Processes Information Technology

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Interoperability Virtualization	Data analytics and Artificial intelligence Communication and Networking Cybersecurtiy

(continued)

(continued)

Principles	Technologies
Decentralized Integrated business processes	Cloud Mobile technologies

Questionnaire

1. How far along are you with your IT security solutions? (Lichtblau et al. 2015)

	Solution planned	Solution in progress	Solution implemented
Security in internal data storage			
Security of data through cloud services			
Security of communications for in-house data exchange			
Security of communications for data exchange with business partners			

2. Are you already using cloud services? (Lichtblau et al. 2015)

	Cloud-based software	For data analysis	For data storage
Production, Logistics and Procurement			
R&D—Product development			
After sales services			
Sales and Distribution channels			
Pricing/Promotion			
Human resources			
Information technology			
Finance			

3. Do IT dashboards be used for traceability of company processes?

No
Yes

4. How would you evaluate your equipment infrastructure when it comes to the following functionalities? (Lichtblau et al. 2015)

	No, not available	Yes, to some extent	Yes, completely
Machines/systems can be controlled through IT			
M2 M: machine-to-machine communications			
Interoperability: integration and collaboration with other machines/systems possible			

Smart Business Processes
Smart Finance

Principles	Technologies
Real time data management (Collection/Processing/Analysis/Inference) Decentralized	Data analytics and Artificial intelligence Cloud

Questionnaire

1. Do you perform real-time cost calculations with data obtained from production?

No
Yes

2. Do you analyze company's cash flow and investments on a historical basis?

No
Yes

3. To what extent do you utilize from financial data when make investment decision?

None
Low
Medium
High

4. To what extent are your financial systems automated?

None
Low
Medium
High

5. How do you perform financial risk measurement?

None
Historical basis
Real-time

Strategy and Organization
Business Models
Questionnaire

1. Do your existing products and services comply with innovative digital business models?

No
Yes

2. To what extent are you aware of the "As-a-service" business model? (The University of Warwick Maturity Model)

No awareness.
Aware of concept with some initial plans for development
High awareness and implementation plans are in development
"As-a-service" has been implemented and is being offered to the customer

3. Which degree of resource is allocated to digital business models?

None
Low
Medium
High

4. Is the current business model of the company evaluated and updated during the interim period in the matter of digitization?

No
Yes

5. To what extent do you monetize your new data-driven services?

None
0–2.5%
2.5–10%
Over 10%

Strategy and Organization
Strategic Partnerships
Questionnaire

1. Does your company have partnerships for Industry 4.0 projects with following options?

None
Academics
Technology providers
Suppliers
Customers

2. How would you describe the implementation status of your Industry 4.0 strategy? (Lichtblau et al. 2015)

No strategy exists
Pilot initiatives launched
Strategy in development
Strategy formulated
Strategy in implementation
Strategy implemented

3. Do you use indicators to track the implementation status of your Industry 4.0 strategy?

No, our approach is not yet that clearly defined
Yes, we have a system of indicators that gives us some orientation
Yes, we have a system of indicators that we consider appropriate

Strategy and Organization
Technology Investments
Questionnaire

1. Which technologies in your company are driving Industry 4.0?

None
Data analytics and Artificial intelligence
Adaptive robotics
Simulation
Embedded systems
Communication and Networking
Cybersecurity
Cloud
Additive manufacturing

(continued)

(continued)

Virtualization technologies (VR & AR)
Sensors and Actuators
RFID and RTLS technologies
Mobile technologies

2. To what extent do you allocate sufficient budget to investments in Industry 4.0?

None
Low
Medium
High

3. How often do you conduct a cost/benefit analysis for Industry 4.0 investment? (The University of Warwick Maturity Model)

No measurable Industry 4.0 investment yet
No ongoing review of cost/benefit analysis for Industry 4.0 investment yet
Annual cost/benefit analysis of Industry 4.0 investment
Quarterly cost/benefit analysis of Industry 4.0 investment

4. In which parts of your company have you invested in the implementation of Industry 4.0? (Lichtblau et al. 2015)

	Planning investment	Investment done
Production, Logistics and Procurement		
R&D—Product development		
After sales services		
Pricing/Promotion		
Sales and Distribution channels		
Human resources		
Information technology		
Finance		

Strategy and Organization

Organizational Structure and Leadership

Questionnaire

1. Are business units/project teams structured in interdisciplinary in the company?

No
Yes

2. Is there any business unit to maintain relationship or communicate with customers?

No
Customer service
Customer relationship management

3. Is there any data-driven organizational structure? (Data scientists, analytics team, digital transformation director, etc.)

No
Yes

4. To what extent are employees equipped with relevant skills for Industry 4.0? (The University of Warwick Maturity Model)

Employees have little or no experience with digital technologies
Technology focused areas of the business have employees with some digital skills
Most areas of the business have well developed digital and data analysis capability
All across the business, cutting edge digital and analytical skills are prevalent

5. Do you have training for the digital transformation in the company?

No
Yes

6. How is your IT organized? (Lichtblau et al. 2015)

No in-house IT department (service provider used)
Central IT department
Local IT departments in each area (production, product development, etc.)
IT experts attached to each department

7. To what extent do departments collaborate with each other? (The University of Warwick Maturity Model)

The business operates in functional silos
There is limited interaction between departments (i.e. S&OP process)
Departments are open to cross-functional collaboration
Departments are open to cross-company collaboration to drive improvements

8. To what extent does the leadership team support Industry 4.0? (The University of Warwick Maturity Model)

Leadership team does not recognize the value of the Industry 4.0 investments
Leadership team is investigating potential Industry 4.0 benefits
Leadership team recognizes the financial benefits to be obtained through Industry 4.0 and is developing plans to invest
Widespread support for the Industry 4.0 within both the leadership team and across the wider business

9. How is your Industry 4.0 team organized to execute innovative projects?

There is no employee for Industry 4.0 projects
There are employees for Industry 4.0 project; but in different business units
There are employees for Industry 4.0 project in the same business unit

10. Is there any working environment where OT/IT units work together?

No
Yes

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