Readiness and Maturity Assessment Model to Measure the Industry 4.0 Ecosystem

Alagiri Govindasamy and **Arivarasi Arularasan**

Abstract Industry 4.0 is a pragmatic phenomenon happening across the world and clearly defining the silver line between winners and losers from today's market place. There is heightened awareness and seriousness found among the organizations to embrace the Industry 4.0 ecosystem to take first-mover advantage from the industry, but this process is not a smooth one due to inherent challenges from this long journey. Many times, organizations are lacking the necessary competency and skillsets to implement Industry 4.0 framework, and often they are looking for external partners help to chart out tactical and strategic digital road maps. One of the gaps found from the literature is the non availability of the comprehensive Industry 4.0 readiness and maturity assessment mechanism to support organizations. In this article, we are proposing an extensive Industry 4.0 readiness and maturity assessment framework with necessary building blocks to provide an accurate and robust decision support mechanism to organizations. The proposed industry 4.0 mechanism has unique propositions to assess nine different vital organizational constructs-like digital leadership and digital operations and classify companies into five maturity quadrants to make an informed decision on their quest for industry 4.0 journey. This theoretical model will provide an unbiased reflection about the organization's current technical capability and socio-cultural approval for Industry 4.0 ecosystem adoption. Limitations and potential future research areas are discussed in this article.

Keywords Industry 4.0 · Cyber-physical systems (CPS) · Assessment and maturity model

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1   Introduction

Organizations across the world are sitting in a crossroad where there never witnessed the high impact from emerging technologies as they are facing on today. Incidentally, Industry 4.0 is a promising framework to address various stakeholders' expectations from present questionable global economy and to excel in the market place [1]. Berman and Bell [2] argued that the success of organizations will get determined by the degree of Industry 4.0 framework adoption and this stand explains the irreversible digital transformation journey option available to all organizations. Various studies highlighted the constructive and larger role from Industry 4.0 on the broader society and labor market as a whole, apart from obvious benefits to organizations like increased productivity improvement and reduced new product development time.

Many times, organizations are lacking the necessary competency and skillsets to measure their current state of readiness to implement Industry 4.0 ecosystem, and often they are looking for external expert's help to chart out tactical and strategic digital road maps. We intend to address the below research questions from this study. Research question 1 (RQ 1): How to define a comprehensive Industry 4.0 assessment framework to measure the current state of organizational readiness? Research question 2 (RQ 2): How to determine Industry 4.0 maturity level for an organization based on assessment outcome? The proposed industry 4.0 assessment mechanism has unique propositions to assess various vital organizational elements to make an informed decision to adopt Industry 4.0 journey. This article explains the innovative industry 4.0 maturity classification model based on assessment outcome.

2   Literature Review

2.1   The Role of Industry 4.0

Industry 4.0 is the strategic initiative from the German government as part of the 'High tech strategy 2020 action plan' in 2011 [3]. The fundamental concept for Industry 4.0 is interconnectedness, to establish a real connection among various stakeholders from Cyber-Physical System [4]. Six important design principles from Industry 4.0 are interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity [5]. One main differentiator of Industry 4.0 from earlier three industrial revolutions is that the fourth industrial revolution is affecting entire organizational functions, not limiting with productivity improvement objectives noticed from the previous three industrial revolutions [6].

The motto of Industry 4.0 is to shrink the gap between physical and digital paradigms by the autonomous exchange of data among critical elements like a machine, man, sensors, actuator, and products and establish intelligent coordination among them without manual intervention. Mrugalska and Wyrwicka [5] explain the important role played by three important components namely the Smart Product,

the Smart Machine, and the Augmented Operator and this author explained the critical role played by each of these components. In the conventional business context, human beings are wielding the upper hand in controlling other resources, but in case of Industry 4.0, the cyber-physical system (CPS) will results in the seamless communication between all stakeholders like machines, man, sensors, and products, thus diminishes the dominating role by employees [7]. Important elements like data acquisitions, data processing, machine-to-machine communication, human–machine interaction, and decentralized decision-making environment with intelligent mechanisms are hallmarks from an able cyber-physical system as part of Industry 4.0 [8].

2.2 The Current State of Industry 4.0 Assessment and Maturity Mechanism

'The Industry 4.0 readiness online self-check for business' developed by RWTH Aachen University, Germany is a promising mechanism to assess various parameters from an organization's readiness [9, 10]. The 'Industry 4.0 maturity index' by Acatech given a framework to measures the digital footprint for an organization by comparing the current state and future state [9]. This assessment tool is designed for manufacturing companies and no scope to factor existing business philosophies in a place like a Lean system. 'The System Integration Maturity Model for Industry 4.0' proposed by Leyh et al. [11] offers a mechanism to measure an organization's existing IT landscape with 5 stage model in place. This model is not ideal to assess large organizations and non-manufacturing environments. Provisions to measure existing operational philosophies and inner aspects of the digital system are missing from this model. 'The Industry 4.0 Quick Check-up assessment model' offers a window to measure five dimensions. Few notable shortcomings are non-available metrics to assess existing operational philosophies and no provisions to assess the readiness of all organizational entities.

'The Guideline industry 4.0' developed by VDMA offers a five-stage assessment model to measure the digital maturity model for an organization [12]. One notable limitation from this model is that there is no provision to capture critical organizational parameters like culture, digital strategy, and employees. 'The Industry 4.0 Maturity Model' proposed by the Vienna University of Technology offers a model to measure organizational digital maturity [10]. This model contains nine factors with 62 internal dimensions with a provision to assess each dimension with a corresponding weighting factor. One limitation is that this model does not have any provision to measure existing operational philosophies used and no maturity model suggestions found from this model. 'The Production Assessment 4.0' Developed by Fraunhofer IAO [13] contains five focus areas with a two-stage process. One advantage of this model is that there is a provision to factor the expectations from existing operational systems like total quality management.

3   Gaps from the Literature

Most of the existing Industry 4.0 assessment models are focusing on measuring existing IT maturity levels and the importance of managerial inclination. Cultural and operational parameters are not considered from these existing assessments. Another gap found from the literature is that existing industry 4.0 assessment tools do not have provisions to measure the option to integrate existing operational philosophies into Industry 4.0 implementation. Most existing assessment models are either focused on manufacturing organizations or addressing major organizations alone. There is a gap found to have a universal Industry 4.0 assessment tool to fulfill requirements from all industry segments in all sizes. Finally, many existing Industry 4.0 assessment tools do not proclaim the strategies to reach the desired digital maturity state after the initial assessment is done.

4   Proposed I 4.0 Assessment and Maturity Mechanism

The proposed Industry 4.0 assessment mechanism is poised to fill the gaps identified from the previous research studies and provide informed guidance to the management team to identify driving forces, challenges, and potential areas for future investments. In reality, Industry 4.0 implementation is a challenging one irrespective of organization size and complexity, so the proposed mechanism provides comprehensive coverage of all vital organizational parameters to take an informed decision. Refer to Fig. 1 to see the details. The appendix shows the complete questionnaire from the proposed assessment tool.

Here, we address the 'Research question 1 (RQ 1): How to define a comprehensive Industry 4.0 assessment framework to measure the current state of organizational readiness?' with a potential industry 4.0 assessment mechanism.

The digital leadership dimensions will measure the incumbent executive team's awareness about Industry 4.0, tolerance level, and readiness to embrace industry 4.0 ecosystem and their strategic direction to allocate sufficient budget to address competitor's actions. **The strategy** dimension will address the expectations from current operations philosophies, tactical and strategic focus areas, any priority areas identified, emerging technologies utilization, and potential pilot study areas to adopt Industry 4.0 ecosystem. **Business model** dimensions will capture the potential revenue generation from the digital way of doing business, explore options to introduce digital features to existing product portfolio, and to leverage other supply chain stakeholders to achieve higher digital maturity. **Product portfolio** factor explains the product flexibility to leverage digital technologies, availability of necessary infrastructure in place to leverage data, agile approach in new product introduction, and companies' agility and flexibility to adopt digital mode of business. **Digital operations** perspective explores the organization's existing infrastructure readiness to use emerging technologies, good data generation mechanisms through a sufficient
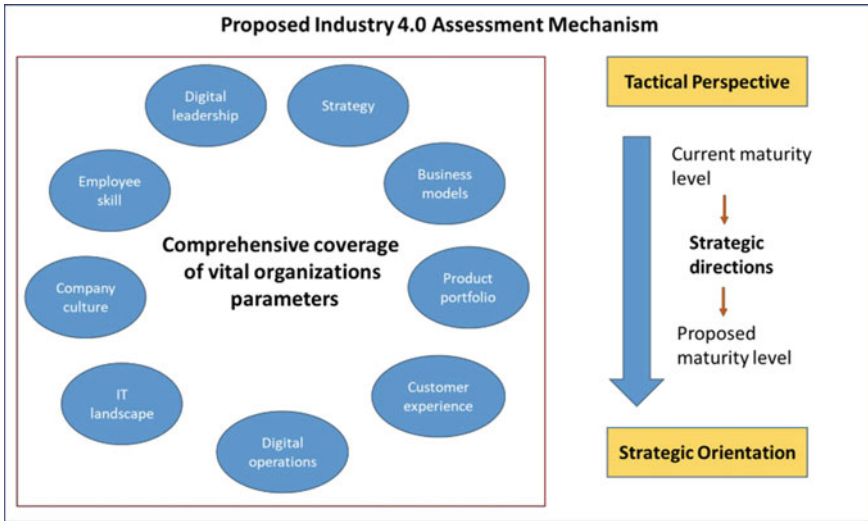
Fig. 1 Proposed industry 4.0 assessment mechanism

array of sensors, access critical parameters from anywhere, the degree of digital maturity from current operations and the extent of width and breadth of organizational functions covered by industry 4.0 system. ***IT Landscape*** is a crucial function to assess whether existing IT infrastructure is good enough to address Industry 4.0 requirements, sufficient IT flexibility to connect with all stakeholders from the supply chain, and enough security features to address ever-increasing cyber threats. ***Company culture*** is perhaps the deciding factor to determine the outcome from any major initiative like Industry 4.0 as the proposed system cannot last long without full approval from employees across the hierarchies. This assessment block will find out any dedicated training and mentoring program to prepare the employees for Industry 4.0 projects. ***Employee skill*** dimension will explore whether existing employees need additional training programs for Industry 4.0 challenge or organization can go outside to choose capable third party agencies to bring industry 4.0 skilled resources. The ***customer experience*** dimension will examine the existing digital mechanism's capability to address ever-increasing customers' desire to do business through digital means and potential digital solutions identified to ensure seamless communication with customers.

Organizations can be classified into five maturity stages as per the outcome from the proposed Industry 4.0 assessment mechanism (Refer Fig. 2). Here, we address the '*Research question 2 (RQ 2): How to determine Industry 4.0 maturity level for an organization based on assessment outcome?*' with the proposed Industry 4.0 maturity model.

Stage 1: Digitization: This is the minimum required phase to kick-start the digital transformation in any organization. The idea behind this stage is to put an IT system to replace manual activities into the digital mode. ***Stage 2: Digitalization:*** This is
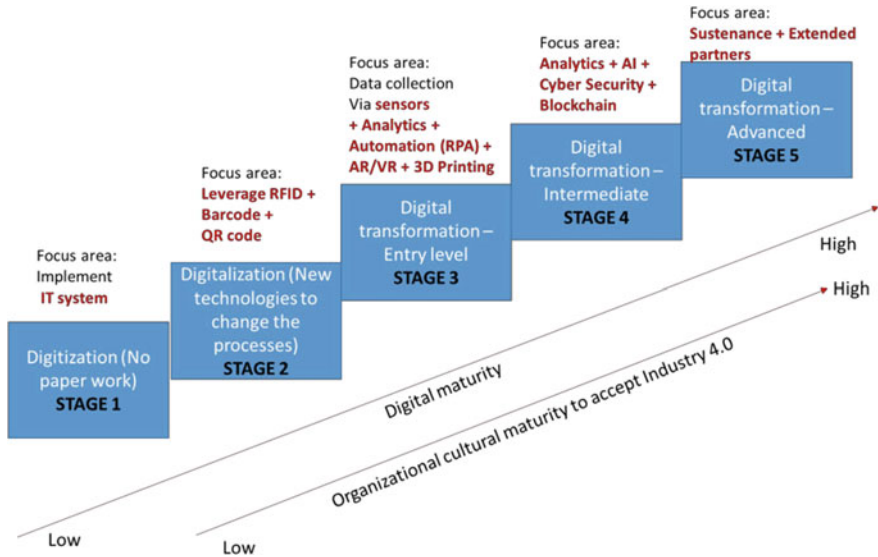
Fig. 2 Proposed industry 4.0 maturity model

the phase to implement higher-order technologies like RFID, bar code, and QR code to bring the next level of automation to enhance existing business processes and introduce new revenue generation platforms.

Stage 3: Digital Transformation—Entry Level: Data is the fundamental element for critical Industry 4.0 elements like big data platform, data analytics including machine learning and deep learning and artificial intelligence. The viable option is to generate such a massive amount of data is through installing sensors as per given requirements. Robotic Process Automation (RPA) technology and the usage of virtual reality and augmented reality technologies can be leveraged across various business functions. *Stage 4: Digital Transformation—Intermediate Level:* Industry 4.0 elements like data analytics and artificial intelligence can be used in this phase to leverage the extensive availability of data from various sources collected from the previous phase. The usage of advanced functions like Blockchain can be leveraged here to bring a high degree of transparency and singe truth across the organizational boundaries. The necessity of strong cybersecurity to protect organization IT and the proposed digital system is an important criterion here. *Stage 5: Digital Transformation—Advanced Level:* This is the phase where organizations have to start sustaining their Industry 4.0 investments and benefits. The role of solid cybersecurity is crucial here as the entire organization starts to work in a near smart manufacturing concept with an autonomous decision support system in place. Another driving factor is to integrate the organization's industry 4.0 ecosystem with other stakeholders like suppliers and customers to get true benefits.

5 Limitations and Future Research Areas

One of the limitations is this proposed industry 4.0 assessment model has to be implemented across many organizations to validate the expected outcome and to ensure the effectiveness. The chance to test this industry 4.0 assessment mechanism across countries will enhance the general acceptance of this model by the industry. Another limitation is this assessment model has to be filled by many people from an organization to avoid individual bias. This assessment model is giving the same treatment to all existing operational strategies like Lean and TQM, there may be some necessity to design a dedicated assessment mechanism for each dedicated operational systems in place. Potential future areas for research activities may include provisions for measuring nonoperational parameters like financial aspects to gain a comprehensive assessment for an organization.

6 Conclusions

Days are not far away to witness Industry 4.0 will alter the competitive positioning from the industry and a deciding factor to determine industry leaders. The non-availably of necessary data leads to the management team's biased approach toward Industry 4.0 and may hamper their decision-making abilities to frame necessary polices to proceed with Industry 4.0 ecosystem implementation. The proposed industry 4.0 assessment mechanism augments the management team's decision-making process backed by solid data points. The management team can chart out strategic plans with clear identification of challenges from the Industry 4.0 journey, which helps them to adopt reasonable expectations and clarity on the benefits from Industry 4.0 investment decisions. This proposed solution address the executive team's desire to acquire ground realities, provide necessary data points, and give confidence to them to embark Industry 4.0 journey.

Appendix: Digital Transformation (Industry 4.0) Assessments Instrument

Industry:
Nature of business:
MNC/Domestic Company:
Country:
City (Operations):
Turnover (In USD):
Number of employees:
Number of years in operation:

Type of company:

Sl. No.	Parameter	Questions
1	Digital leadership	Does the leadership team believe that the industry 4.0 paradigm will make a profound impact on the traditional way of doing business from your organization?
2		Are you ready to implement all I 4.0 digital components to become a leader in your industry?
3		The leadership team has taken some attempts to implement I 4.0 digital solutions across the organization?
4		Are you determined to start investing I 4.0 platform in this year?
5		There is a budget provision for I 4.0 other than typical IT budget for your organization
6		Are you witnessing competition from your peers for Industry 4.0 adoption? What is your immediate expectation from I 4.0? (Like Increase revenue, reduce cost, increase the quality, increase customer connect, create transparent in business operation)
7	Strategy	Do you have a dedicated designation like Chief Digital Officer in your organization?
8		Are you sure that you want to formulate various management strategies based on real-time data from the Cyber-Physical System environment from the organization?
9		Are you clear on how to kick start Industry 4.0 journey from your organization?
10		Which I 4.0 technology you are going to year adopt in this and next year
11		Do you need an experienced Industry 4.0 expert outside from your organization to implement I 4.0
12		What are the business areas prioritized for 4.0 investment?
13		You want to take a cautious approach to identify potential issues to choose the relevant I 4.0 digital component accordingly
14		Do you want to go for a pilot study to understand the potential benefits from I 4.0 before adopting company-wide implementation
15		Your focus areas from last 1 year for I 4.0 deployment
16		Your focus areas from next 1 year for I 4.0 deployment
17	Business models	Is your entire product life cycle embracing digital solutions (Starting from design to warranty?)

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Sl. No.	Parameter	Questions
18		Are you determined to generate significant revenue from digital-based products and services in the coming years?
19		Do you foresee higher demands from your customers for digital features from your products and services?
20		Do you feel strong digital collaboration with your partners like suppliers and customers as a critical factor to decide your success in the future?
21	Product portfolio	We have the agility and flexibility capabilities in place to fulfill customer expectations by introducing innovative features in the product portfolio
22		We made provision to generate real-time data from our product portfolio, hence we can perform real-time product-related analysis
23		We leveraged digital solutions to introduce prototypes in a fast manner as per changing customer requirements
24		We are ready to explore new business models that run purely on digital solutions
25	Digital operations	What's your organization's maturity in terms of a digital-driven and intelligent automation system?
26		We have a unified digital platform to visualize companywide operations without any manual interventions
27		There is a mechanism available to generate the necessary data from all machines
28		Right now, we can able to access and control data from our regional/corporate offices far away from our factories
29		All critical operational parameters like KPI's are automatically updated through digital channels
30		Our internal functions are relying upon digital channels for coordination and collaboration
31		How do you rate the digital penetration for your vertical value chain?
32	IT landscape	How do you rate the digital penetration for your horizontal chain value chain?
33		Is your existing IT landscape is agile enough to accommodate dynamic needs from critical business parameters like reduce cost and enhance quality?
34		Your IT landscape is digitally connected with your partners like suppliers and customers?
35		Will you form a dedicated I 4.0 team or enhance the skill of existing IT team to execute I 4.0 projects

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Sl. No.	Parameter	Questions
36		Are you sure that the existing IT team is matured enough to address I 4.0 requirements?
37		Are you ready to face cybersecurity risks if you go for a higher maturity level in I 4.0 operations in your organization?
38	Company culture	As a company, do you respect the hidden value of the raw data?
39		How do you rate your I 4.0 maturity in your organization?
40		Do you agree that I 4.0 journey is a significant change management program for your organization?
41		Are you sure that your employees are culturally matured enough to accept I 4.0 adoption?
42		Do you have any mechanism to encourage I 4.0 suggestions from your employees
43	Employee skills	Are you confident that your internal team can execute I 4.0 projects?
44		We already using digital solutions for employee competency building activities like e-learning and inline training classes
45		We already using the digital repository for knowledge management
46	Customer experience	Our organization adopted Omni digital strategy to reach out the customer
47		We determined to leverage emerging technology to engage with the customer
48		We have a digital mechanism to capture customer feedback from all digital channels, ex: social media
49		We give high importance to leverage digital solutions to address customer feedback to enhance our products and services
50	Others	Tell us your challenges to embrace I 4.0 in your organization

Note The quantitative questions are measured in 1–5 Likert scale

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