

# Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review

Key ingredients for evaluating Industry 4.0

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## Abstract

**Purpose** – Industry 4.0 is the present trend in automation and data exchange in organizations. However, till today, there is no generic and common understanding in terms of assessing the Industry 4.0 readiness for organizations. The purpose of this paper is to identify the key ingredients for assessing Industry 4.0 readiness for organizations, the interrelationships that exist between these readiness factors and how future research should proceed given the research findings.

**Design/methodology/approach** – A systematic literature review (SLR) methodology of Tranfield *et al.* (2003) was employed to ensure the replicability and transparency of the review process. Altogether, 68 articles were identified for the final thematic analysis.

**Findings** – The SLR results generated six broad themes of readiness factors. The interrelationship mechanism between these factors was identified. In addition, 17 research propositions were elucidated.

**Research limitations/implications** – Being the first literature review on assessing Industry 4.0 readiness for organizations, it finds 17 research propositions which will give the future researchers a guideline for further research in Industry 4.0.

**Practical implications** – Although Industry 4.0 is the buzzword, very few organizations understand the concept in detail. This paper will help the organizations to identify the factors which they have to assess critically before implementing Industry 4.0 in an organization.

**Originality/value** – Nevertheless, there has been a lot of research on Industry 4.0; this is the first systematic literature to identify the key ingredients for assessing Industry 4.0 readiness for organizations.

**Keywords** Literature review, Industry 4.0, Cyber-physical systems, Organizations readiness

**Paper type** Literature review

## 1. Introduction

The transformation of organizations to the digital form is commonly known as Industry 4.0. It changes completely the way an organization operates. All the functions of organization undergo a sea change, e.g., from manufacturing to all other activities which take place within and external to the industry changes (Rajnai and Kocsis, 2018). In addition, the economic environments and customer needs also get altered with the new wave of integrated digitization of the organization (Lee *et al.*, 2014). There are academic debates as to whether such digitization of organizations can be called the fourth industrial revolution (Bassi, 2017). The concept was originally initiated in Germany, followed by acceptance by other countries. The main feature of Industry 4.0 is cyber-physical systems (CPS) production, which is based on the heterogeneous data and knowledge integration (Lu, 2017; Zanero, 2017). The key roles of CPS are to achieve the agile and dynamic requirements of production. They should also aim to improve the efficiency and effectiveness of the complete organization. Industry 4.0 includes many technologies, which include Internet of Things (IoT), Internet of Service (IoS), cloud-based manufacturing, radio frequency identification (RFID), enterprise resource planning (ERP)



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and social product development (Baur and Wee, 2015; Fonseca, 2018; Georgakopoulos *et al.*, 2016; Kube and Rinn, 2014; Lasi *et al.*, 2014; Lin *et al.*, 2016; Lom *et al.*, 2016; Lu, 2017; Singer, 2015). The current trend in organizations is digitalization and Industry 4.0; nevertheless, in a recent survey, some leaders from Industry expressed that they have not even heard about it. Some leaders knew about it; however, they do not know how to implement it or, in other words, how to get an organization ready for implementing Industry 4.0 (Rajnai and Kocsis, 2018). Transforming an organization to digitalization means changing the strategy of the overall organization, which is a big decision to undertake. Assessing the readiness of the organization for Industry 4.0 is based on self-assessment instrument. Some models investigate the detailed information on the organizations in IT (Gill and VanBoskirk, 2016; Gokalp *et al.*, 2017; Leyh *et al.*, 2016; Menon *et al.*, 2016). The PwC Industry 4.0 survey of 2016 introduced PwC maturity model of Industry 4.0 (Industry, 2016). The Industry 4.0 maturity model was described in the ACATECH study (Schuh *et al.*, 2017). The Forrester digital maturity model captures the complexity and maturity of the digital transformation of enterprises in four dimensions (Gill and VanBoskirk, 2016). A thematic analysis of these models transpires that the assessment dimensions conceptually differ from model to model. Furthermore, none of these models offers any generic and widely accepted methodology for assessing the Industry 4.0 readiness for organizations (Lu, 2017; Rajnai and Kocsis, 2018; Schumacher *et al.*, 2016). In this study, we intend to address this gap by systematically reviewing the prior literature and to investigate the factors which are responsible for assessing the readiness of Industry 4.0 for the organization. The literature review is conducted with the aim to answer the following research questions:

- RQ1. What are the key ingredients for assessing the readiness for Industry 4.0 for organizations?
- RQ2. What interrelationships will exist between these readiness factors?
- RQ3. How should future research proceed given our research findings?

## 2. Theoretical background

In order to meet the ever-changing customer demands in a highly competitive environment, the manufacturers have to be agile, efficient, responsive and also be cost effective by continuously reducing the operational costs (Fatorachian and Kazemi, 2018). This is achieved by the high level of digitization and automation within and external to the organization's supply chain (Rashid and Tjahjono, 2016). Within the organization, there is a vertical integration of various subsystems such as manufacturing, human resources, planning, procurement and other functional subsystems. Automation in manufacturing environments has been used for a long time. However, there were limited benefits due to automation because automation was used within some of the manufacturing processes and all other functional systems within the business were not integrated (Fatorachian and Kazemi, 2018; Da Xu, 2011). Another reason for the limited success was the lack of interoperability of different interfaces or communication mechanisms (Gruhier *et al.*, 2017), leading to misalignment between automation technologies. Industry 4.0 involves the connection and integration of virtual and physical world through CPS and IOT through intelligent objects which constantly communicate and interact with each other (Öberg and Graham, 2016) to meet the predetermined strategic objective. Therefore, implementing Industry 4.0 is a major strategic decision and before taking such an important decision, organizations have to assess the readiness of the organization for implementing Industry 4.0

(Rajnai and Kocsis, 2018; Schumacher *et al.*, 2016). Maturity models are one of the most commonly used tools to assess the maturity of the organization or a process or processes to assess the ability to achieve the desired targets. The readiness models primary aim is to capture the starting point and allow for initializing the development process (Schumacher *et al.*, 2016). One of the most well-known readiness models is “IMPULS – Industrie 4.0 Readiness.” Table I depicts various industry readiness and maturity models.

The analysis of the maturity models suggests that though there is growth in research trend on Industry 4.0, there is also a research gap on the use of maturity models while implementing Industry 4.0 (Gokalp *et al.*, 2017). The evaluation criteria, dimensions and items are different for various models and also there is no standard and well-accepted model (Akdil *et al.*, 2018; Gokalp *et al.*, 2017; Schumacher *et al.*, 2016). In addition, the domain of most of the dimensions of these models was focused on assessing the IT readiness. Therefore, there is a need for understanding the key ingredients to assess the readiness factor for implementing Industry 4.0 in a holistic perspective.

Model name	Source	Assessment approach
The Connected Enterprise Maturity Model (2014)	RockwellAutomation (2014)	It has five stage processes to implement Industry 4.0. There is technology focusses assessment in the four dimensions. There are no much details about item and development
IMPULS – Industrie 4.0 Readiness (2015)	Lichtblau <i>et al.</i> (2015)	There are six dimensions for assessment. There are 18 items which measure the readiness in five levels. It also defines the barriers and specific recommendations to overcome are also specified
Empowered and Implementation Strategy for Industry 4.0 (2016)	Lanza <i>et al.</i> (2016)	This model offers a quick assessment of Industry 4.0 maturity. It is a process model for realization. It can be used for gap analyses. Its use as a toolbox for incapacitating maturity barriers is also possible. However, there are no details about items and development process offered
Industry 4.0/Digital Operations Self-Assessment (2016)	PricewaterhouseCoopers (2016)	This model has online self-assessment in six dimensions. The emphasis is on digital maturity in four levels in each phase. The application as consulting tool for assessment is required in three of the six dimensions. Also, there is no details about items and development process offered
Industry 4.0 readiness and maturity of manufacturing enterprises	Schumacher <i>et al.</i> (2016)	Their model defines nine dimensions. The emphasis was on extension of existing models and tools through its strong focus on organizational aspects. The model focus on transforming the abstract concepts of smart manufacturing into items that can be measured in real production environments
Maturity model for Industrial Internet SIMMI 4.0	Menon <i>et al.</i> (2016) Leyh <i>et al.</i> (2016)	The research is a preliminary study of assessing the industrial internet maturity The model has five maturity stages and three dimensions of integration
Industry 4.0 – MM	Gokalp <i>et al.</i> (2017)	The dimensions of the proposed model are based on SPICE, and process attributes of SPICE are replaced by a total of nine aspect attributes
Maturity and Readiness Model for Industry 4.0 Strategy	Akdil <i>et al.</i> (2018)	Propose a model which considers the principles of real-time data management, interoperability, decentralized and service oriented

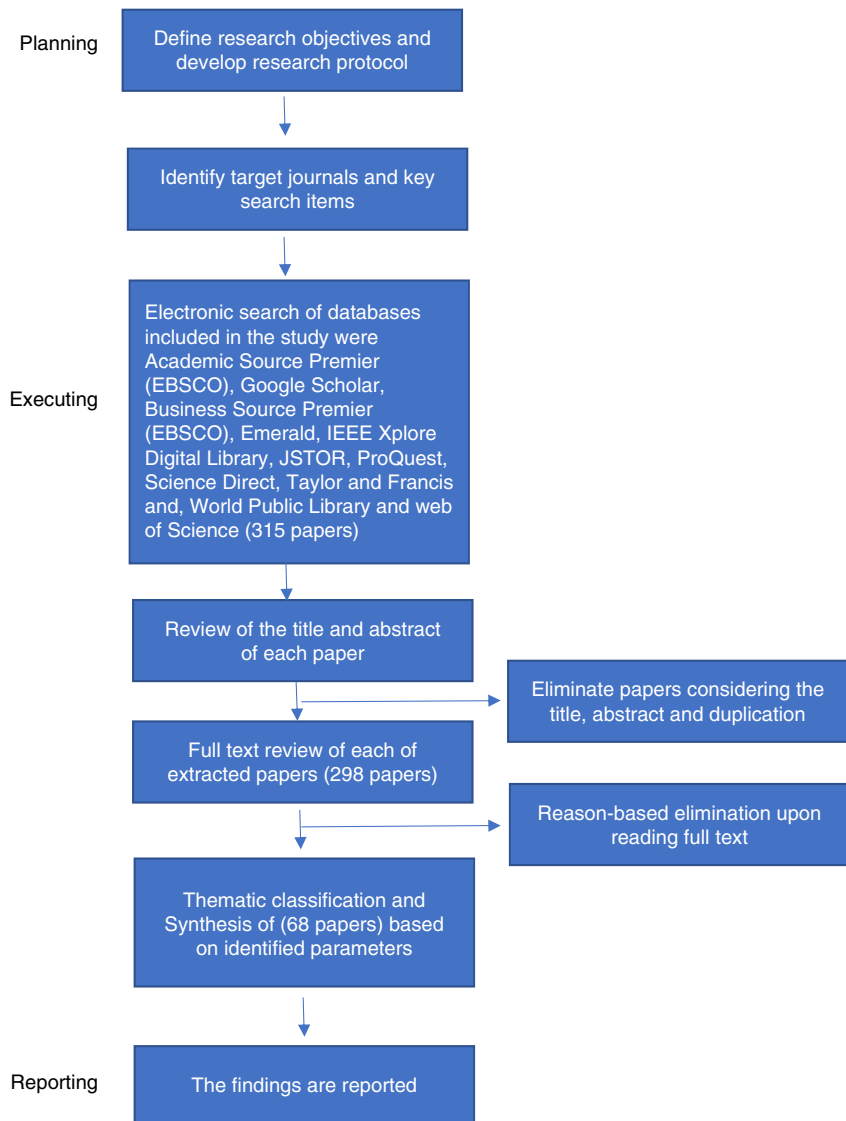
**Table I.**  
Industry 4.0 maturity models

### 3. Research methodology

To achieve the goal of adding to the extant knowledge on the key ingredients for assessing the readiness of the organizations for Industry 4.0, the SLR methodology of Tranfield *et al.* (2003) was deployed. The methodology adopted for this review is shown in Figure 1.

#### 3.1 Data sources

The first phase involved searching electronic databases. The keywords used for searching the databases were as follows: Industry 4.0, readiness factor for Industry 4.0, success factors for Industry 4.0, Organization readiness for Industry 4.0, Industry 4.0 readiness, Cyber-Physical



**Figure 1.**  
Systematic review methodology

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System readiness, Cyber-Physical Production System readiness, Cyber-Physical Sensor System readiness, Cyber-Physical Human System readiness, Cyber-Physical Assembly System readiness and Cyber-Physical System Platform.

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### 3.2 Screening

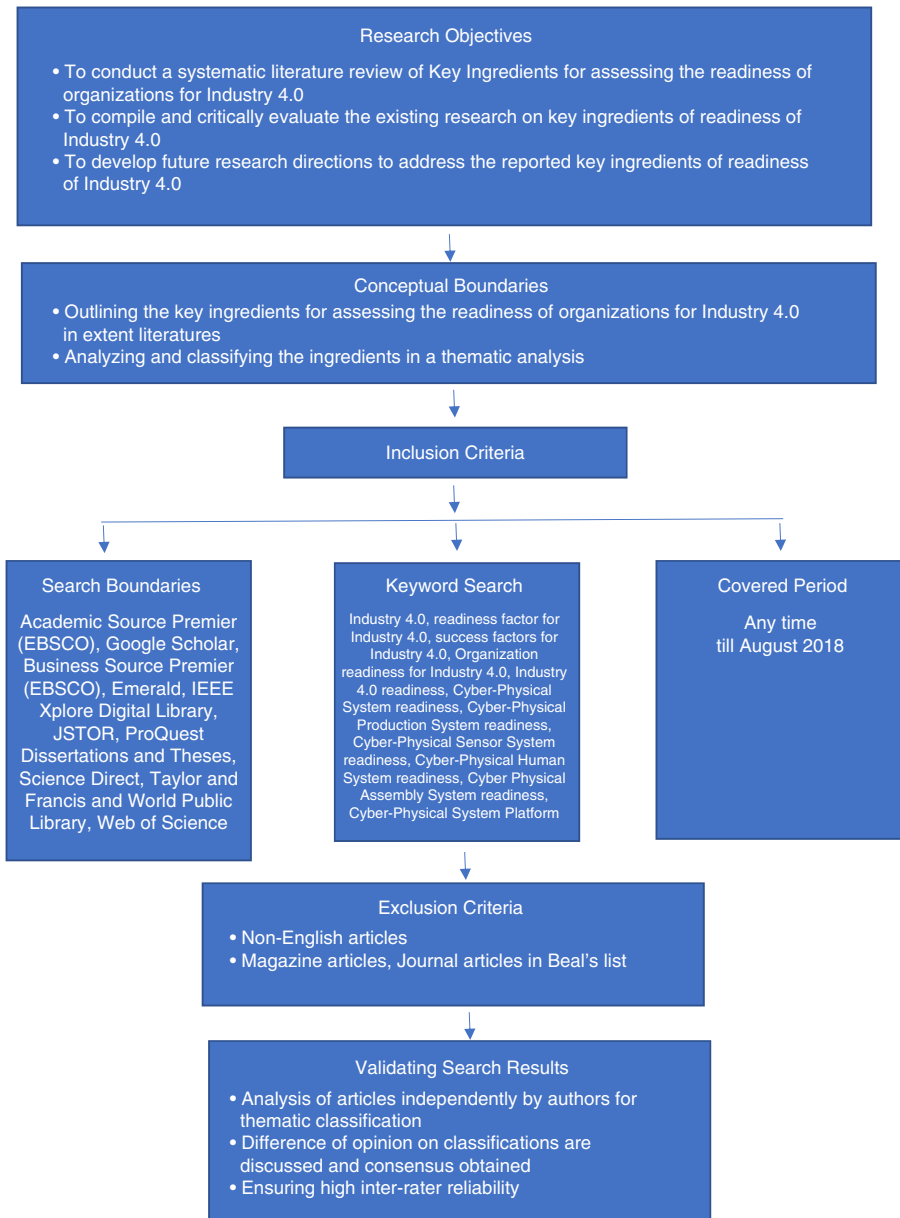
The databases included in the study were Academic Source Premier (EBSCO), Google Scholar, Business Source Premier (EBSCO), Emerald, IEEE Xplore Digital Library, JSTOR, ProQuest Dissertations and Theses, Science Direct, Taylor & Francis, World Public Library, Scopus and Web of Science. Though scholars have recommended the exclusion of conference proceedings from SLR (Scott-Findlay and Estabrooks, 2006), the present study included the same for extracting insights on this emerging field of research area (Flick, 2015). This phase involved the screening of articles for review. A literature review protocol based on Popay *et al.* (2006) was developed to limit the systematic error and bias in the screening of papers for review. This protocol summarized the scope, strategy and data extraction method for the review, as shown in Figure 2. This research used the protocol to obtain the final sample of articles. The first step was a broad search of the literature review to find abstracts that met the screening criteria, i.e., Readiness for Industry 4.0, Success factors of Industry 4.0, Ingredients of Industry 4.0, Industry 4.0 Success and Industry 4.0 Challenges, in the title or abstract of the article. The titles and abstracts were analyzed. It helped in removing the duplicates. The remaining abstracts were screened using the inclusion/exclusion criteria which were earlier stated. The full articles were then read to meet the inclusion/exclusion criteria. The reference list of articles was read to further improve the search criteria. The total number of articles along with the breakup is shown in Figure 1.

### 3.3 Data analysis

As the primary goal of this research was to explore the key ingredients for assessing the readiness of organizations for Industry 4.0, it was decided to identify the patterns, directions, similarities and differences in key ingredients within the sampled articles (Burke and Hutchins, 2007; Conn *et al.*, 2003; Smith *et al.*, 2009; Whittemore, 2005). In total, 68 articles were extracted after review considering the research objective of the study. To ensure that the identified papers really dealt with the objective of the research, the papers were read by both the authors independently. The papers were reflected on in terms of themes of readiness factors for Industry 4.0 emerging in the studied literature. The themes were further analyzed independently by both the authors and classified into master themes. The rationale of the classification scheme was to meet the goal of parsimony to explain the key ingredients of readiness factor for Industry 4.0. This was required because different maturity models have many different factors to explain the readiness. The objective of the study was to find the master theme behind these large numbers of factors. The master theme reflected the categorical classification of the theme as a higher order cluster or categorization (Whittemore and Knafl, 2005). The interrater agreement calculated among both the authors for the classification scheme using Cohen's  $\kappa$  (Wood, 2007) for the process was found to be 0.87, denoting substantial agreement (McHugh, 2012). The categorized articles are tabulated in Table II.

### 3.4 Descriptive analysis of literature

The descriptive analysis of articles was conducted. Figure 3 shows the country-wise distribution of articles. In total, 32 percent of the articles are from Germany, followed by the USA 16 percent, Italy 9 percent, Austria and the UK at 7 percent, tailed by China at 5 percent and others. As expected, Germany is leading; however, other countries are catching up. Besides there are articles from countries like Morocco suggesting widespread acceptance of



**Figure 2.**  
Literature review protocol

the concept of Industry 4.0. Figure 4 shows the analysis of research methods used in the selected articles. In total, 39.7 percent of the articles follow conceptual viewpoint, 30.9 percent case study, quantitative methods like survey accounted for 20.6 percent and literature review 8.8 percent. The conceptual and case studies dominate, suggesting the area of key readiness factor for Industry 4.0 is just building up. It also further submits the huge need for future research to test the viewpoint and theories suggested in case studies.

Sr. No.	Themes	Articles
1	Organization strategy	Brettel <i>et al.</i> (2014), Erol, Schumacher and Sihm (2016), Santos <i>et al.</i> (2017), Schumacher <i>et al.</i> (2016)
2	Level of digitization of the organization	Baheti and Gill (2011), Bassi (2017), Brettel <i>et al.</i> (2014), Hofmann and Rusch (2017), Lasi <i>et al.</i> (2014), Lee <i>et al.</i> (2014, 2015), Lichtblau <i>et al.</i> (2015), Meyer <i>et al.</i> (2009), Monostori (2014), Rubmann <i>et al.</i> (2015), Schlechtendahl <i>et al.</i> (2015), Storey and Song (2017), Weyer <i>et al.</i> (2015), Zanero (2017), Zuehlke (2010)
3	Extent of digitization of supply chain	Ben-Asher and Gonzalez (2015), Burke <i>et al.</i> (2017), Douaioui <i>et al.</i> (2018), Erol, Jager, Hold, Ott and Sihm (2016), Gokalp <i>et al.</i> (2017), Hofmann and Rusch (2017), Ivanov <i>et al.</i> (2016), Jazdi (2014), Leyh <i>et al.</i> (2016), Lichtblau <i>et al.</i> (2015), Liu and Xu (2017), Tan <i>et al.</i> (2016), Watanabe <i>et al.</i> (2005), Yen <i>et al.</i> (2014)
4	Smart product and services	Akdil <i>et al.</i> (2018), Axelsson <i>et al.</i> (2018), Baines <i>et al.</i> (2009), Bassi (2017), Cheng <i>et al.</i> (2016), Kagermann (2015), Lee <i>et al.</i> (2014), Lerch and Gotsch (2015), Leyh <i>et al.</i> (2017), Liao <i>et al.</i> (2017), Lichtblau <i>et al.</i> (2015), Martinez <i>et al.</i> (2010), Menon <i>et al.</i> (2016), Mont (2004), PricewaterhouseCoopers (2016), Rennung <i>et al.</i> (2016), Saldivar <i>et al.</i> (2015), Shrouf <i>et al.</i> (2014), Vandermerwe and Rada (1988), Wan <i>et al.</i> (2016)
5	Employee adaptability with Industry 4.0	Benešová and Tupa (2017), Borman and Motowidlo (1993), Charbonnier-Voirin and Roussel (2012), Lee <i>et al.</i> (2015), Lichtblau <i>et al.</i> (2015), Palazzeschi <i>et al.</i> (2018), Pinzone <i>et al.</i> (2017), Pulakos <i>et al.</i> (2000), Wolf <i>et al.</i> (2018)
6	Top management involvement and commitment	Bauer <i>et al.</i> (2015), Brettel <i>et al.</i> (2014), Dent and Goldberg (1999), Jazdi (2014), Palazzeschi <i>et al.</i> (2018), Schmidt <i>et al.</i> (2015), Shamim <i>et al.</i> (2016), Thong <i>et al.</i> (1996)

Table II. Readiness factors

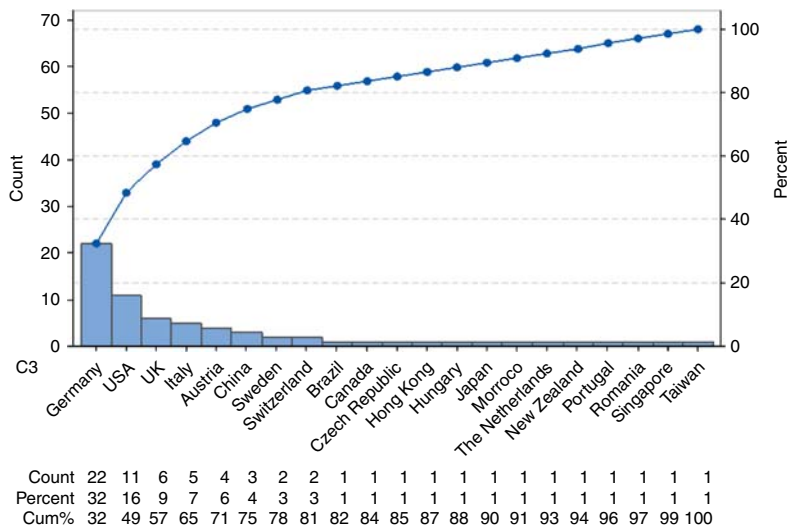
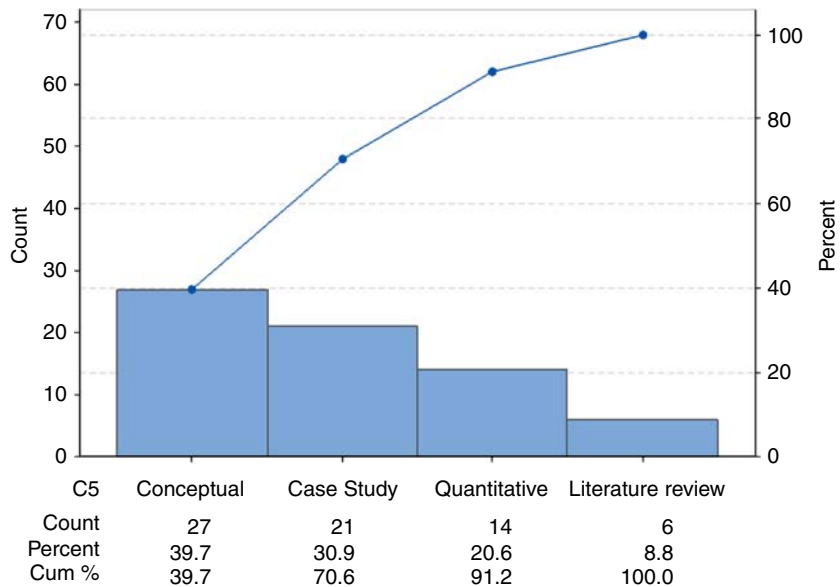


Figure 3. Country-wise distribution of articles

#### 4. Thematic analysis of literature

In this section, the themes extracted from the review of academic research on the key ingredients for assessing the readiness of organizations for Industry 4.0 are enumerated and explained to achieve the research objective of the study.



**Figure 4.**  
Research method wise  
distribution of articles

#### 4.1 Readiness of organizational strategy

The scope of Industry 4.0 does not start and end with supply chain or productions; rather, it encompasses every aspect of organization, sector and even society (Brettel *et al.*, 2014). Consequently, the impact of Industry 4.0 on organization strategy will be decisive. The long-term relationships that will get changed due to Industry 4.0 within an organization are between organization and nature: this includes developments in resource efficiency and sustainability of manufacturing systems; organization and local communities: it leads to increased geographical proximity and acceptance, and integration of customers in design and manufacturing processes; organization and value chains: the distributed and responsive manufacturing through collaborative processes enables mass customization of products and services; organization and humans: this includes human-oriented interfaces and improved work conditions (Santos *et al.*, 2017). Therefore, the organizational strategy will be significant in each of these relationships and consequently, it will be one of the most important ingredients for assessing the readiness of the organizations for Industry 4.0:

- P1. Organizational strategy for implementing Industry 4.0 will have to take into consideration the anticipated changes of the relationship between (a) organization and environment; (b) organization and communities; (c) organization and value chains; and (d) organization and humans apart from the technical aspect of implementation.

The information and communication enabled technologies facilitate the networked manufacturing systems, implying information interchange, interoperable systems, and decentralized decision making and control (Santos *et al.*, 2017) and warrant an all-encompassing strategic viewpoint:

- P2. Throughout the implementation of Industry 4.0, there should be an organizational strategy for the technical aspect of implementation, e.g., ICT-enabled technologies which primarily allow networked manufacturing systems, implying interoperable systems, information interchange and decentralized decision making and control.



The organizational strategy will have to be devised for the huge initial investments due to Industry 4.0 implementation from ICT to innovation management within the organization. Companies, on the one hand, are finding it difficult to grasp the understanding of Industry 4.0 and relate it to their specific domain of business. Sometimes it is difficult for the company to appreciate Industry 4.0 as a vision or mission (Erol, Schumacher and Sihm, 2016). The means vs ends interpretation of Industry 4.0 is not clear, thus leading to confusion for the organizations. The lack of understanding of the concept of Industry 4.0 in clear terms with respect to the existing business creates confusion in generating organization strategy. In other words, it leads to difficulty to identify the strategic fields of actions for the implementation of Industry 4.0. The elements of organizational strategy like vision, mission, values, long- and short-term goals, action plans, KPI's, SWOT analysis, etc., will be immensely impacted by Industry 4.0 (Schumacher *et al.*, 2016). The marriage of digital and physical technologies will result in a different experience for the diverse stakeholders leading to the management of core strategic issues:

- P3. Most of the elements of organizational strategy like vision, mission, values, long- and short-term goals, action plans, KPI's, SWOT analysis, etc., will change with the implementation of Industry 4.0.

#### 4.2 Level of digitization of the organization

The level of digitization of organizational assets can be termed as the percentage of assets which are equipped with sensors, which sense the various parameters of relevance. The extent to which an organization uses the data from the sensors is integrated for greater transparency in operation and planning purposes (Lichtblau *et al.*, 2015). The implementation of Industry 4.0 means highly automated production. The smart workpieces will control and monitor the production process on their own. The highest level of implementation of Industry 4.0 means the smart pieces will guide themselves with artificial intelligence resulting in less human intervention (Bassi, 2017). The manufacturing, production and distribution systems will coordinate within themselves without much human interaction (Meyer *et al.*, 2009; Weyer *et al.*, 2015; Zuehlke, 2010). This is possible through a CPS which connects the physical aspects of the organization like production, logistics, etc., with the cyber world, e.g., algorithms through an IT infrastructure what is called IoT (Baheti and Gill, 2011; Lee *et al.*, 2015; Zanero, 2017):

- P4. The degree of integration of cyber-physical assets within an organization will determine the success of Industry 4.0 implementation.

Data collection, data processing, data dissemination and decision making are digitized. Such an approach will lead to better utilization of resources of the organization (Storey and Song, 2017). It also requires an online collaboration interface between various functions of the organization, e.g., production systems, information systems and humans (Lichtblau *et al.*, 2015; Monostori, 2014). Thus, for such a thing to happen, the level of digitization within the organization must be very high:

- P5. Automated data management from the organization assets will lead to better automated decisions-making models using Industry 4.0 within the organization.

The production system is composed of various machines. The machines cannot be operated in isolation, but they follow a system of operation to create a product or service. These systems are manual requiring a high level of human interaction or completely automated which necessitates a low level of human interaction (Lasi *et al.*, 2014; Schlechtendahl *et al.*, 2015). To implement Industry 4.0 completely, it entails a complete integration of machines

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with organization systems. The complete digital modeling of all machines and system will result in total integration. The level of data collection should be comprehensive, automated and digital (Brettel *et al.*, 2014; Rubmann *et al.*, 2015):

P6. By integrating organization assets, e.g., machines with organization systems, the Industry 4.0 will optimize the resource utilization.

The big data which are generated should be organized, stored, analyzed and reported timely to the decision-making models within the organization (Lee *et al.*, 2014). Complete implementation of Industry 4.0 results in autonomous decision making within major functions in an organization (Hofmann and Rusch, 2017). For this to happen, the IT systems within the organization should completely support all the organization processes and they should be fully integrated (Lichtblau *et al.*, 2015):

P7. The IT systems in organization should completely support and be compatible with all the organizational processes leading to the better implementation of Industry 4.0.

#### 4.3 Extent of digitization of supply chain

Industry 4.0 suggests digitization of all operations within the entire supply chain and integration of physical systems with cyber worlds. Due to the digitization and integration of physical and cyber systems across the supply chain, a large amount of data acquisition, data interpretation and control is possible so that all the elements in the supply chain can benefit immensely (Tan *et al.*, 2016). A large amount of data sharing can result in new production planning models in the supply chains of the organization (Lichtblau *et al.*, 2015). Likewise, better supply chain modeling and management is conceivable due to this integration. The smart workpieces moving along the supply chain will create the need for better production planning and control models based on the real-time big data. This will be guided using a regulatory component using self-guided systems (Erol, Jager, Hold, Ott and Sihm, 2016). The supply chain in smart factories has a dynamic structure which changes as per the needs of customers. The dynamic structures are a challenge to implement using algorithms. For instance, short-term scheduling in such smart supply chains is a challenge because of temporal machine structures, different processing speeds at parallel machines and dynamic job arrivals (Ivanov *et al.*, 2016). Therefore, new algorithms are needed to manage supply chains in the smart factory:

P8. The supply chain management in Industry 4.0 will have incorporate challenges such as real time, data intensive and dynamic structural organization between various elements in the supply chain, resulting in a need for new algorithms.

Production and logistics are interrelated; therefore, Industry 4.0 to be successful, the logistics should provide production systems with the input factors needed at the right time, in the right quality and in the right place (Douaioui *et al.*, 2018; Hofmann and Rusch, 2017). The logistics must be adaptive and intelligent. It should consider better real-time monitoring of material flows, better transport management and precise management of risks. It also means a logistic system which adapts flexibly and quickly to a volatile environment based on the increased availability of information (Douaioui *et al.*, 2018). Another challenge would be in times of the decentralization and individualization of production; logistics tasks become more flexible and intelligent when the objective is to better optimize costs, time and resources. The challenges for logistics due to the implementation of Industry 4.0 warrant also a smart logistics. However, the challenges of smart logistics are also enormous. The extent of digitization of supply chain is an important challenge. The level of digitization will vary from comprehensive within the company integration to partial external to the company digitization. A system which is partially integrated will not be able to derive optimal

benefits of Industry 4.0 (Lichtblau *et al.*, 2015). The use of autonomously guided workpiece within the organization or entire supply chain is also another challenge (Watanabe *et al.*, 2005). If the autonomous guidance is selective in areas, the benefits may not that great compared to autonomous guidance across the supply chain:

*P9.* Autonomously guided workpiece systems should be implemented across the supply chain through the use of smart logistics for better success of Industry 4.0.

Self-reacting processes are processes which react based on data without any human intervention (Burke *et al.*, 2017). Such a concept if implemented within the organization and across the supply chain can result in an immense benefit for the organization. Partial implementation of self-reacting processes will hinder the benefits of Industry 4.0:

*P10.* Self-reacting processes across all elements of the supply chain will result in improved alignment of flows, integrating functions, coordinating processes, designing of complex systems and managing resources while the implementation of Industry 4.0.

The IT security systems are an important area for the success of Industry 4.0. The IT systems are vulnerable to cyber attacks (Ben-Asher and Gonzalez, 2015). The security of IT within and external to the organizations will make the Industry 4.0 a sustainable success (Jazdi, 2014). The CPS when implemented in the organization supply chain result in a large amount of data. For management of such a large amount of data and its software, cloud-based tools are most important for its success (Liu and Xu, 2017). The success of Industry 4.0 is also based on the success of the deployment of cloud-based technologies in the integration of CPS (Yen *et al.*, 2014):

*P11.* IT system security and cloud-based data management implementation will result in data protection and management of all stakeholder's data in the supply chain resulting in the success of Industry 4.0.

#### *4.4 Smart product and services*

Product and services are the important components for the success of Industry 4.0 (Leyh *et al.*, 2017; Liao *et al.*, 2017). The concept of the smart factory under Industry 4.0 is facilitating the automated, flexible and efficient production of the products and services (Lichtblau *et al.*, 2015). Products are assembled from smart workpieces which are modular and plug compatible (Axelsson *et al.*, 2018). These are equipped with sensors, RFID, communication interfaces, GPS, etc., to collect data from the environment and their own status about production. These data will be processed in the cyber systems to guide their path in the production system. Similarly, the cyber world will guide all the functions of production process in an autonomous manner without human interaction. Of course, all these happen in the real time (Lichtblau *et al.*, 2015; Saldivar *et al.*, 2015). This integration of products, physical production systems and cyber technology will enable the monitoring, self-regulation and optimization of the resources to manufacture individual products (Bassi, 2017; Cheng *et al.*, 2016):

*P12.* Integration of products and services with other CPS of the organization will enable the monitoring, self-regulation and optimization of resources resulting in the successful implementation of Industry 4.0.

Such a viewpoint does not end with the production of the product alone, but rather, it moves beyond production to consumption by the customer. The concept of servitization was proposed as early as 1988 (Vandermerwe and Rada, 1988). This concept of customer focus should combine products, services, support and knowledge as the most important

elements (Lee *et al.*, 2014). Manufacturing servitization is defined as the innovation of organizational capabilities and processes from product sales to integrated product services (Baines *et al.*, 2009). It is a change in strategy for the organization wherein organization shift their capabilities and processes from selling of a product to selling an integrated product and service offering that deliver value in use (Martinez *et al.*, 2010):

*P13.* The product and service offering in organizations should be innovatively designed to sell an integrated product and service offering that deliver value in use for the customer resulting in the success of Industry 4.0 implementation.

Product-service system is a special aspect of servitization. It is a system of product, services, supporting networks and infrastructure, which is designed to be competitive in the market, meet the customer needs, and above all, it has less impact on the environment when compared with products of traditional nature (Mont, 2004). Therefore, the marketing goal of the organization changes from not just selling a product to satisfying customer needs by total service solution (Lerch and Gotsch, 2015). For such a concept to be a reality, the integration of the CPS of the organization should integrate the usage of each product at the consumer end:

*P14.* The integration of the CPS of the organization should be integrated with end customers for creating new service opportunities due to the implementation of Industry 4.0.

It is a challenge but when integrated with consumer end usage pattern, the big data must be mined to create a unique service experience of each consumer. The service engineering and management can be a significant element in the success of Industry 4.0. There is a need to use existing service management tools like “PEM 7” in addition to Industry 4.0 to derive implementation benefits from Industry 4.0 in order to impart the service management principles to Industry 4.0 (Rennung *et al.*, 2016). This is necessary as the service industry is growing and also the customers are also increasingly expecting products and services:

*P15.* Service management principles should be integrated with Industry 4.0 for designing services which will satisfy increasing customer expectations of product-service system.

The data from downstream supply chain will result in a huge opportunity for the organizations for design new services, which are customizable to each user needs (Lichtblau *et al.*, 2015; Shrouf *et al.*, 2014; Wan *et al.*, 2016). The after sales of products will be more on actual data driven from product usage and condition monitoring giving scope to new business models. In addition, there is a scope for designing autonomous service systems which will cater the needs of the customers based on the data usage (Kagermann, 2015; Lichtblau *et al.*, 2015; Wang *et al.*, 2017). The physical products should compulsorily have an IT component which will collect the data and transmit to the cyber systems and intelligently devise a customized service, which can be executed through the physical systems of the service provider.

#### *4.5 Employee adaptability with Industry 4.0*

Implementation of Industry 4.0 implements a new working environment. Most of the work traditionally done by the workers will now be done by the CPS in the smart factory (Palazzeschi *et al.*, 2018). Therefore, most of the traditional skills valued by the traditional organizations will be redundant. This will force the workers to acquire new skills of higher order nature (Pinzone *et al.*, 2017). The employee who will adapt to these new job requirements will survive. The requirements of production workers will be more with the new age skills like IT and critical thinking (Wolf *et al.*, 2018). A skill for lifelong

learning will also be very important for the success of employees. The areas of skill requirements will be IT infrastructure, automation technology, data analytics, data security/communications security, development or application of assistance systems, collaboration software, non-technical skills such as systems thinking or process understanding (Benešová and Tupa, 2017; Lichtblau *et al.*, 2015). Employee performance in the workplace was characterized as a single global indicator reflecting the characteristics of professional success or meeting the set of objectives (Charbonnier-Voirin and Roussel, 2012). This is a black box concept like efficiency, where the focus was only on the results. This led to researchers trying to explain what happens inside the black box leading to the in-depth study of the performance aspect. The performance was thus regarded as a multidimensional phenomenon reflecting various behaviors needed to accomplish the various objectives of the organization. The task and contextual performance were studied as the distinct concept (Borman and Motowidlo, 1993). The dynamic nature of changes in the environment and their effects on the nature of work, management, empowerment practices, etc., has led to the concept of adaptability of employees at work. The adaptability of employees can be differentiated from other employee behaviors. Pulakos *et al.*(2000) were the first who brought to light the various dimensions of adaptability an employee has to go through in light of various changes in the workplace (Pulakos *et al.*, 2000). Due to the implementation of Industry 4.0, there will be changes in the traditional nature of employment and the structure of work. These include changes in individual responsibilities, assignments and relationships (Lee *et al.*, 2015; Lichtblau *et al.*, 2015; Wolf *et al.*, 2018). These changes call for employees to adapt to various dimensions of adaptability. For instance, the employee must adapt to learning new skills of IT and critical thinking skills to adapt to the CPS integration in a smart factory. He must adapt to new technologies and new ways of doing work in a smart factory. The degree of employee adaptability increases as the changes in workplace change; in addition, the dimensions of adaptability also undergo a change. These changes in work models will warrant new models of adaptability:

*P16.* Smart employee adaptability models will have to be developed to predict the adaptability of employee during the implementation of Industry 4.0.

#### *4.6 Top management involvement and commitment*

The top management involvement and commitment will be very imperative for the accomplishment of successful implementation Industry 4.0. The continuous support of top management will be one of the most important ingredients for the readiness of the organization for Industry 4.0 (Shamim *et al.*, 2016). In both large and small organizations, the implementation of Industry 4.0 will require enough organizational resources (Jazdi, 2014). The top management involvement and commitment will be a major factor for diverting these organizational resources:

*P17.* Top management involvement and commitment will help in diverting the organizational resources for the successful implementation of Industry 4.0.

From the technical perspectives, the organizational resources could be increasing digitalization and automation of the manufacturing environment and the introduction of a digital value connection to increase communication between products and their environment and business partners (Brettel *et al.*, 2014; Palazzeschi *et al.*, 2018; Schmidt *et al.*, 2015). Technical innovation is important for implementing Industry 4.0, but psychological resources are also very important (Bauer *et al.*, 2015). The holistic management of human resources will be a major factor in the success of the Industry 4.0 (Palazzeschi *et al.*, 2018). The top management involvement and commitment will act as a

motivation for sustaining the new initiative (Thong *et al.*, 1996). The top management is highly influential within the organization and it will help to overcome the resistance (Dent and Goldberg, 1999) and hence will help to accept Industry 4.0 by various stakeholders within the organizations.

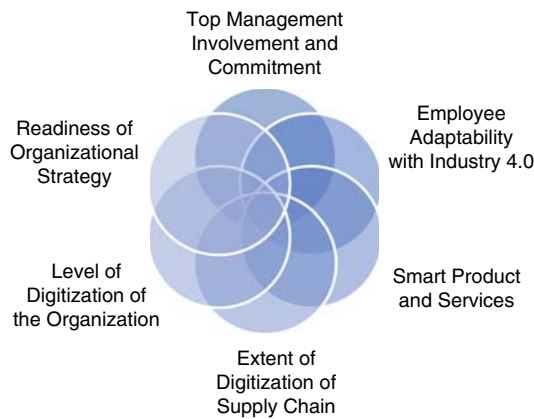
#### *4.7 Interrelations among key readiness factors for Industry 4.0 in organization*

Industry 4.0 will impact the total functioning of the organization from organization strategy to manufacturing and from the design of products and services to productivity (Bassi, 2017). Therefore, the readiness factors which are elucidated above will be interrelated. The top management involvement and commitment will have a positive interrelation with organization strategy (Miles *et al.*, 1978), level of digitization of organization, extent of digitization of supply chains, smart products and services (Bassi, 2017; Lichtblau *et al.*, 2015; Rajnai and Kocsis, 2018) and employee adaptability (Charbonnier-Voirin and Roussel, 2012; Ilgen and Pulakos, 1999; Sony and Mekoth, 2014a). Organization strategy is the main driving force which can influence the level of digitization of the organization and the extent to which the products can be smart within the organization (Bassi, 2017; Lichtblau *et al.*, 2015; Weyer *et al.*, 2015). Therefore, the organizational strategy will have positive interrelationships with the level of digitization and extent the products and services are made smart. The extent of digitization of supply chain may have an interrelationship with organization strategy (Poirier and Bauer, 2000); however, the extent of cooperation of other elements in the supply chain is also very significant (Albino *et al.*, 2007). Organization strategy will have an interrelationship with employee adaptability (Charbonnier-Voirin and Roussel, 2012; Pulakos *et al.*, 2000; Sony and Mekoth, 2014b). An organization which trains employees will have a good chance of being adaptable to the new skill requirements (Sony and Mekoth, 2014b) of Industry 4.0. However, individual employee's readiness to acquire new skills will also play a major role in this relationship. There will be interrelations between the level of digitization of the organization, the extent of digitization of supply chain, smart product and services and employee adaptability with industry 4.0. In this relationship, the employee adaptability may vary significantly because the degree of skill required to manage the systems in the transition phase will be different than when the implementation of a system with full implementation is done (Charbonnier-Voirin and Roussel, 2012; Ilgen and Pulakos, 1999; Pulakos *et al.*, 2000; Sony and Mekoth, 2014b).

The key ingredients for assessing the readiness of organization for implementing Industry 4.0 are depicted in Figure 5.

## **5. Conclusion and limitations**

Industry 4.0 arguably symbolizes the beginning of the fourth industrial revolution. It represents the current trend in automation technologies in the organization. It includes technologies like CPS, IoT and cloud computing. Despite all the hype, many organizations are lacking know-how as to the concept of Industry 4.0 with respect to their existing business domain. To make the matter further difficult, there is no general model for assessing the readiness for Industry 4.0 for the organization. Therefore, it is important to collate and analyze these literatures on the readiness of Industry 4.0 for better understanding the readiness factors for Industry 4.0 in organizations. This study used an SLR methodology to analyze the key ingredient in detail through a thematic analysis. In addition, the interrelationship between these factors is also analyzed. The review is limited by the databases accessed, the search criteria, method of searching, inclusion and exclusion criteria and the time constraints.



## Key ingredients for evaluating Industry 4.0

**Figure 5.** Key ingredients for assessing readiness of organization for Industry 4.0

### 5.1 Implications for research and practice

There has been a huge interest among academicians about Industry 4.0. The propositions unearthed in this study can be used as a research direction for the future research. The impact of the organization strategy on the successful implementation of Industry 4.0 should be studied in different sectors. Such studies will help to clarify the variations in success factors across different types of sectors. Industry 4.0 will change the relationships between organization and environment, organization and communities, organization and value chains, organization and humans and future studies can be directed as to what components of organizational strategy must be designed for considering these changing relationships. The level of digitization within the Industry and the success of Industry 4.0 would need to be classified in a typological analysis. In addition, the critical success factors, which will motivate the existing supply chains to adopt Industry 4.0, need to be understood in different types of supply chains. How does the power, value, performance, risks, etc., vary with the implementation of Industry 4.0 will lead to a better understanding of supply chain dynamics. The supply chain strategy for implementing Industry 4.0 will have to be classified and analyzed for all four elements in the supply chain such as integration, operations, purchasing and distribution. The disruption risks in supply chain and Industry 4.0 will enable to clarify the various disruption risks which may increase or decrease due to vertical, horizontal and end-to-end integration in a supply chain. Industry 4.0 and employee adaptability will be an important research area. Smart employee adaptability models will have new dimensions, on which employees should rely for making Industry 4.0 a success. Qualitative studies and case studies on the type of top management support and its impact on the success of Industry 4.0 will be significant to understand the factors important for the implementation of Industry 4.0. The six key ingredients for assessing the readiness of the organization are interrelated to each other, and therefore quantitative studies may explore the nature of interrelationships. As an aid to practice, the consultants and organizations can use the ingredients suggested here to implement Industry 4.0. Organizations can design their strategy based on the anticipated changes in various relationships due to the implementation of Industry 4.0. The digitization strategy of the organization is most important for the success of Industry 4.0. The digitization strategy should be clearly designed for CPS, IOT and IOS. In addition, there should be a well-designed strategy for converting existing products into smart ones. The organizations can also make use of this study to design the horizontal strategy across the supply chains. All six key ingredients are important for the successful implementation of Industry 4.0 because they are interrelated and therefore, organizations should consider these six factors in totality while implementing Industry 4.0.

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