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Conceptualising Industry 4.0 readiness Model Dimensions: An exploratory sequential mixed-method study

Purpose: Organizations use Industry 4.0 readiness models to evaluate their preparedness prior to the implementation of Industry 4.0. Though there are many studies on Industry 4.0 readiness models, the dimensions of readiness differ. Besides, there is no study empirically validating the readiness model in different sectors or types of organization. The purpose of this study is to conceptualise the dimensions of the Industry 4.0 readiness model and subsequently evaluate the criticality of these dimensions in manufacturing, service, small and medium sized enterprises (SMEs) and large enterprises (LEs).

Methodology: The study uses an exploratory sequential mixed method design. In phase one, 37 senior managers participated through a purposive sampling frame. In phase two, 70 senior managers participated in an online survey.

Findings: The results of the study indicated that the Industry 4.0 readiness model has 10 dimensions. Further, the criticality of the dimensions as applied to different sectors and type of organizations is put forward. This study will help manufacturing, services, SMEs and LEs to evaluate Industry 4.0 readiness before commencing the deployment of Industry 4.0.

Practical Implications: The findings can be very beneficial for Industry 4.0 practitioners and senior managers in different organisations to understand what readiness dimensions need to be considered prior to implementation of Industry 4.0 technology.

Originality of Value: This paper makes an attempt to conceptualise the Industry 4.0 readiness model and utilises an exploratory mixed method for critically evaluating the dimensions related to the model.

Keywords: Industry 4.0, Readiness Model, Industry 4.0 implementation, Interviews, Surveys

1. Introduction

Industry 4.0 represents a new trend in automation and data exchange and many organizations are trying to implement it across the globe (Caiado et al., 2021; Váně et al., 2021). The first step before implementing Industry 4.0 is to assess whether an organization is ready to deploy Industry 4.0 (Krishnan et al., 2021; Rajnai & Kocsis, 2018). The readiness model of Industry 4.0 is described as the "*degree to which organizations can take advantage of Industry 4.0 technologies*" (Hizam-Hanafiah et al., 2020a). There are many Industry 4.0 readiness models developed in both practitioner and academic literature (Michael Sony & Naik, 2019a). Within these models, organizations can be classified as being in a not ready or almost ready state (Hizam-Hanafiah et al., 2020a). These models vary concerning Industry 4.0 model dimensions (Hizam-Hanafiah et al., 2020b), (Gokalp et al., 2017). There is currently a common understanding of the dimensions of the Industry 4.0 readiness model (Michael Sony & Naik, 2019a). Hizam-Hanafiah *et al.* (2020) identify key six dimensions of the Industry 4.0 readiness model through a systematic literature review (Hizam-Hanafiah et al., 2020a). A similar study was done by Sony and Naik (2019) through a systematic literature review. The authors had identified six broad themes of the generic Industry 4.0 readiness model[7]. These two studies were systematic literature reviews and need empirical validation as regards to the dimensionality from a pragmatic point of view (Acioli et al., 2021; Hizam-Hanafiah et al., 2020a; Michael Sony & Naik, 2019a). There is also a need to explore if there are any additional dimensions of Industry 4.0 from the perceptions of both manufacturng and service organizations as well as small and medium-sized enterprises (SMEs) and large enterprises (LEs). Thus the authors intend to explore the research question; "W*hat are the dimensions of the Industry 4.0 readiness model"?* Industry 4.0 readiness dimensions criticality may vary in manufacturing and service organizations (M Sony & Aithal, 2020b) due to the inherent differences in these organizations. Besides, the dimensions criticality may also vary based on

whether it is an SME or LE, as the challenges these organizations face would be different (Brozzi et al., 2018; Stentoft et al., 2020). Thus, the authors intend to explore the second research question ; "*What are the very critical dimensions of the Industry 4.0 model in the manufacturing and service sectors and in SME's and LE's?"*

The paper is organized as follows, in the next section a brief review of the literature of the Industry 4.0 readiness model is carried out, followed by the research design. The findings of a qualitative study are delineated subsequently followed by a ranking of the dimensions using a quantitative study. It is followed by the implications of organizations conclusions, limitations of the research and directions for the future research.

2. Background

There has been an exponential growth in the number of studies in relation to Industry 4.0 readiness models (Botha, 2018). Most of these models are complex, less pragmatic and also do not take into account the changing goals of the organization (Hizam-Hanafiah et al., 2020a). Felch, Asdecker and Sucky (2019) conducted a detailed analysis in terms of the model's applicability to business practice. They suggest that not all Industry 4.0 readiness models are relevant or applicative. Some of these models are designed for specific industries and others are generic (Felch et al., 2019b). They further suggest that empirical validation of these models has not been conducted. Though these models have contributed to expanding the understanding of Industry 4.0 readiness models, however, there is a possibility that these models can vary in terms of short, medium or long-term purpose or benefits (Erol et al., 2016). Another challenge to study these Industry 4.0 readiness models is that they are proprietary properties of organizations and institutions, hence not available in the public domain (Hizam-Hanafiah et al., 2020a). From the perspective of previous important studies, Brozzi has studied the Industry 4.0 readiness model from its applicability in SME, however,

empirical validation was not done (Brozzi et al., 2018). Sony and Naik (2019) through a literature review proposed six dimensions namely top management involvement and commitment, employee adaptability with Industry 4.0, smart products and services, the extent of digitization of the supply chain, level of digitization of the organization and readiness of organization strategy (Michael Sony & Naik, 2019b). They also proposed how these factors are interrelated. Hizam-Hanafiah et al. (2020) through a literature review suggested technology, people, strategy, leadership, process, and innovation as dimensions of Industry 4.0 readiness models (Hizam-Hanafiah et al., 2020a). Both these models are derived from the literature review and have not been empirically tested. Besides, as Industry 4.0 readiness models will be used by organizations, for this reason, it is pertinent to examine the dimensions of the Industry 4.0 readiness model from the perspective of a pragmatic approach. Thus, this study intends to conceptualise Industry 4.0 dimensions from an organizational perspective to compare or contrast the applicability of the dimensions from the organization's viewpoint.

3. Research Design

As previous studies were not conclusive on the dimensionality of the Industry 4.0 readiness model(Hizam-Hanafiah et al., 2020b), exploratory sequential mixed method design(Cameron, 2009) was used. As the phenomenon under study was complex, different methods are needed for exploring the construct dimensionality (Byrne & Humble, 2007). This research first conducts a qualitative study to explore the dimensions of the Industry 4.0 readiness model grounded in data. Subsequently, this model is quantitatively evaluated in a different context. The methodology used in this study is explicated in Figure 1. As there is no conceptual clarity as regards to the conceptualisation of Industry 4.0 readiness model dimensions, this study used a grounded theory methodology to explore the dimensionality of the construct in the qualitative phase. Grounded theory methodology is primarily developed to derive an

explanation about a phenomenon that was non-existent or where the theoretical explanation was inadequate (Charmaz & Belgrave, 2007; Strauss & Corbin, 1994a).

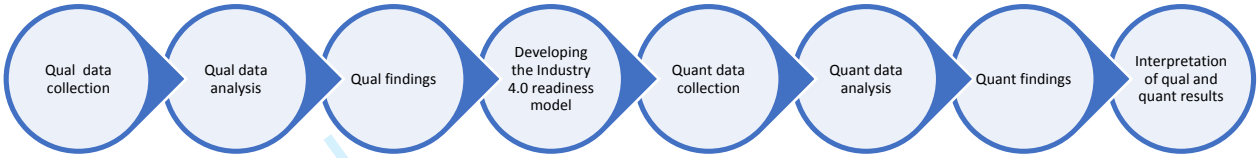

Figure 1: Exploratory sequential mixed method (adapted) (Creswell, 1999)

The next phase was a quantitative phase which was designed to understand the criticality of Industry 4.0 readiness model dimensions in both manufacturing and service sectors as well as in SMEs and LEs.

3.1 Sampling procedure and data collection

The sampling procedure for qualitative data collection primarily revolved around interviews. Senior managers with expertise in Industry 4.0 and working in manufacturing, services, SMEs and LEs were chosen in this study. Senior managers with five years of experience were chosen in this study, because they are directly involved in decision making about various aspects of Industry 4.0 in their organizations, as such the information will be more accurate (J Antony & Sony, 2021; Michael Sony et al., 2020). This study utilised the concept of theoretical sampling (Strauss & Corbin, 1994a). The details about the participants were obtained from LinkedIn because it is one of the most widely used networking sites for professionals (Power, 2015). A personal message was sent to all potential participants outlining the objectives of the study and requesting their voluntary participation in this study.

If a participant agrees to participate, an online interview was conducted. The interviews started with demographic questions around the participants experience in implementing Industry 4.0, followed by open-ended questions such as "*How can one determine if an organization is ready to implement Industry 4.0?"*. Open-ended probing questions were subsequently asked as regards various facets of information expressed by the respondents during the study. The interviews were summarised verbatim and shown to participants within 24 hours to confirm the transcription and to ensure the validity of the data. Pseudo names were assigned to participants such as P1 for participant 1. The data saturation concept was used to ascertain the sample size (Guest et al., 2006). In grounded theory methodology, data collection and analysis is interlayered (Charmaz & Belgrave, 2007) and hence when no new conceptual themes of Industry 4.0 readiness model dimensions were not emerging it was suggested that data saturation was reached.. Figure 2 depicts the demographic profile of respondents. SMEs was classified as an organization with less than 250 employees and above 250 (O'Regan & Ghobadian, 2004) were classified as LEs.

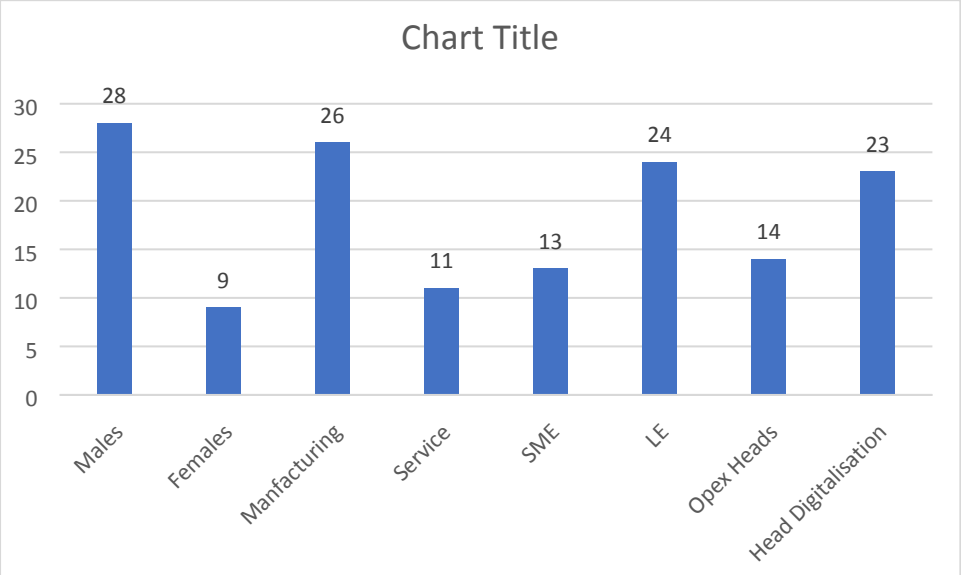

Figure 2: Demographic profile of respondents

In the second phase, the authors used an online survey which was directed to senior management professionals working in manufacturing and service organizations which were either SMEs or LEs. The online survey questionnaire was designed based on the results of qualitative study in terms of the dimensions. The first section was the demographics. The readiness success factors were tabulated and given to respondents. The 7-point Likert scale was used(Dawes, 2002; Sullivan & Artino Jr, 2013). Seven distinct categories were used from "Strongly Disagree" to "Strongly Agree" to capture the responses of the respondents on the Industry 4.0 readiness factors. A seven-point Likert scale is easy to understand and use by the respondents and it has good psychometric properties (Allen & Seaman, 2007). Moreover, as senior management professionals are busy, unnecessary long questionnaires may not be attractive to them. Besides, the short nature of the questionnaire scaffolds respondents in answering the survey in a short period. The revised online survey link was sent out to 250 senior managers who are working in their respective organisations in roles such as Director and Vice President levels. The contacts were obtained through LinkedIn and each of the respondents was contacted through email. A similar research methodology was adopted in previous studies (Jiju Antony et al., 2019), (Jiju Antony et al., 2020). The authors used two criteria in the selection of such subject matter expert; i) all respondents should have a minimum of five years' experience in their role for implementing Industry 4.0 projects, ii) should be working in an organisation as a Technology or Quality Director or similar senior position. Setting such criteria enabled the authors to glean knowledge from high calibre experts within the survey participants, who are responsible for Industry 4.0 in their respective organisations. A total of 70 responses were collated over 13 weeks yielding a response rate of 28%. Easterby-Smith (2012) (Easterby-Smith et al., 2012) argue that a 20% survey response rate is widely considered to be sufficient. The sample characteristics are given in Table 1.

Table 1: Sample Characteristics of the quantitative study			
Row Labels	**LE**	**SME**	**Grand Total**
Manufact	**22**	**19**	**41**
Female	7	3	10
Male	15	16	31
Service	**19**	**10**	**29**
Female	5	3	8
Male	14	7	21
Grand Total	**41**	**29**	**70**

The internal consistency of the 10 Industry 4.0 readiness factors was assessed using Cronbach's Alpha which tests to see if multiple-question Likert scale surveys are reliable. Cronbach's alpha was found to be 0.787. A value of above 0.7 indicates higher internal consistency of the scale (Nunnally, 1994) and gave the researchers confidence that the test designed was accurately measuring the variables of interest. Besides, none of the items correlated in the scale fell below 0.3, indicating a positive consistency of the scale (Hair et al., 2014).

3.2 Data Analysis

For the qualitative data analysis, this study followed grounded theory methodology (Glaser et al., 1968). Three techniques of open coding (creating a list of themes within data), axial coding (categorising or linking subcategories of themes) and selective coding (condensing of specific or excessive categories into higher-order themes) (Hastings et al., 2021). Open coding consisted of identifying individual meaning units, in axial coding these were categorised, or sub-categorised and selective master themes were linked. The data was verified using the member checking technique, memoing to track the themes while coding

and triangulation by multiple investigators (Strauss & Corbin, 1994b) , (Creswell & Poth, 2016), (Merriam & Tisdell, 2015). Microsoft Excel was used for qualitative data analysis because it has a feature of text processing that is used in qualitative data analysis (Bree & Gallagher, 2016; Meyer & Avery, 2009). The 10 dimensions of Industry 4.0 unearthed in this study were subjected to quantitative analysis in phase 2. Cronbach's alpha was calculated for checking the internal consistency of the scale that is, how closely related a set of items are as a group. The mean scores were normalised to identify the most critical readiness factor(Adabre & Chan, 2019)s. Mann Whitney U test was performed to test the difference between the groups in manufacturing, service sectors and between the SME and LE categories. Mann Whitney U test was used as the data did not follow, the normal distribution and it is one of widely suggested non parametric test as a non-parametric alternative to the t-test for independent samples(Milenovic, 2011).

4. Results and Discussion

First, the results of a qualitative study in terms of the dimensions of the Industry 4.0 readiness model are discussed and subsequently, the rankings based on quantitative study are explicated.

4.1 Qualitative Study Results: Ten dimensions of Industry 4.0 readiness model

The ten dimensions of Industry 4.0 are technology readiness, employee adaptability with Industry 4.0, smart products and services, digitalisation of supply chains, extent of the digital transformation of the organization, readiness of Industry 4.0 organization strategy, innovative Industry 4.0 business model, leadership and top management support for Industry 4.0, organizational culture, and employee reward and recognition systems.

4.1.1 Technology Readiness

The respondents in this study remarked on the importance of how ready an organization should be to implement the technologies of Industry 4.0. There are many technologies used in Industry 4.0 such as IoT, RFID, Smart manufacturing, digital twins, Cloud Computing, Robotics etc (Masood & Sonntag, 2020). The technology readiness of the organization depends on how well an organization is ready to implement the technologies of Industry 4.0 in their respective organization to meet the objectives of the organization. This is an important component as organizational success in the implementation of Industry 4.0 will depend on managing these technologies (Sony, M. & Aithal, P.S., 2020). The respondents in this study echoed similar remarks as explicated in table 1. The quotes are verbatim and indicates participant number (P number), as pseudo names are given for anonymity.

Table 1: Excerpts of respondents on technology readiness

"Well, in my opinion, an organization which is ready to accept, understand, implement and adapt the technology to meet the goals of the organization will be the readiest to implement Industry 4.0. To cite an instance if an organization wants to implement vertical integration, however, the systems which the organization uses at present should be compatible for vertical integration. If the existing organization structures are centralised, it will require immense work on the part of the organization to first put a technology-enabled system into practice. How well an organization adapts to the technology enables how well a new organizational structure will determine the success of the implementation of Industry 4.0" . ***P31***
"Industry 4.0 requires the implementation of new technology such as IoT, CPS, Cloud computing, COBOTS to name a few. This will require organizations to adopt these technologies during different phases of implementation of Industry 4.0. The organizations should have adequate technology capability to acquire and use these technologies for

Table 1: Excerpts of respondents on technology readiness
*their benefits". .**P23***
*"An organization which can use new technology will be more ready to implement Industry 4.0. To cite an instance smart sensor should be strategically used to acquire data in real-time and the data should be transmitted strategically so that organizations benefit from it. Industry 4.0 is a leap an organization takes towards automation and data exchange in various organizational activities. So, technology is the central tenant for the application of Industry 4.0. " .**P13***
*"An Industry 4.0 ready organization will be in a position to acquire new technology and continuously use the technology for the success of the organization. It is one thing to acquire new technology and another thing as regards to the continued use of new technology" .**P12***

The technology readiness of the organization will help in deciding to acquire, develop, customise, and transition to Industry 4.0 technology. The circular economy based model suggests that the resources stay in the system as it experiences one of the 10 R's of sustainability (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover)(Bag et al., 2021). Industry 4.0 technologies help to overcome these challenges in the 10 R's system and hence the degree of technology readiness an organization demonstrates in each of the 10 R's will help the organization to be successful.

4.1.2 Employee Adaptability with Industry 4.0

Through automation and data integration, Industry 4.0 digitally transforms an organization to meet its goals. Increased automation in conventional wisdom will suggest workerless production or less human interaction (Sony, M. & Aithal, P.S., 2020). Recent studies suggest

that implementation of Industry 4.0 will result in employees requiring a new skill set, however, employees will be critical for the success of Industry 4.0 (Dworschak & Zaiser, 2014; Hecklau et al., 2016; Weyer et al., 2015). Industry 4.0, thus will have social (human-related) and technical (non-human) components coming together to pursue a common goal commonly known as a socio-technical system (Avis, 2018). Therefore, employees are as important as technology for the success of Industry 4.0 (M. Sony & Naik, 2020). However, with the introduction of manufacturing automation and COBOTS, low skilled workers will temporarily suffer from a lack of employment opportunities. Similarly, advances in artificial intelligence, machine learning, and software automation will impact human employability in an organization.

Table 2: Excerpts of respondents on employee adaptability with Industry 4.0
"*Employees will be key in the implementation of Industry 4.0. An organization whose employees are open to learning new skills will perform better than other organizations while implementing Industry 4.0. It is not possible to lay off employees while implementing Industry 4.0 and recruit new ones. It will have a social, operational, economic impact on the organization, so the organization which has a good employee adaptability program will be more ready to implement Industry 4.0 than an organisation which does not have*" - **P14**
"*Technology is important but the organization whose employees are creative, or they value creativity in problem-solving will be ready to implement Industry 4.0. We need people with the drive to unlearn and relearn new things while implementing Industry 4.0. The solutions to new age problems will not be straightforward or linear, but rather non-linear, complex, and sometimes difficult to solve. Therefore, creative employees or employees who can learn to be creative will survive this onslaught from technology*" - **P31**

"*There will be a variety of technical skills an employee should possess. Besides, soft skills such as teamwork, negotiation, conflict resolution etc will be the need of the hour. I feel employees need to have both technical and soft skills for the success of Industry 4.0 implementation."* **- P29**
"*Employees will have to work with employees from a different department and different fields from their own. They will have to gel with employees from different cultures, values, and belief systems. Hence, employees will have to learn to adapt to working in such environments"* **- P20**
"*The stress of working in a fully automated environment will be different than working in a manual environment. Therefore, employees will have to deal with such stresses to cope with the new Industry 4.0 environment.*" .**P33**

At present, the work which is carried out by university graduates will be done by machines and powerful algorithms (Ford, 2009). Routine jobs will be overtaken by machines and also highly skilled jobs will require pattern recognition and cognitive non–routine tasks (Bonekamp & Sure, 2015). Most of lower-level operational jobs will be taken over by CPS. The implementation of Industry 4.0 results in higher process integration and cross-functional perspectives, resulting in the breakdown of hierarchical levels and decentralisation (Fettig et al., 2018). Therefore, Industry 4.0 will have an impact on all levels of employment and respondent's response are elucidated in table 2. **4.1.3 Smart Products and Services**

The extent to which an organizations product or service is smart plays an important part in deciding how ready an organization is to implement Industry 4.0 (Lichtblau et al., 2015; Michael Sony & Naik, 2019a). The three components of a smart product are 1) physical components like electrical and mechanical elements 2) smart components like microprocessors, sensors, data storage, controls, software, embedded operating system, and

digital user interface. 3) Connectivity components such as ports, antennae, protocols, and networks enable communication between the product and the product cloud, which are run on remote servers and contains products external operating systems (Porter & Heppelmann, 2015). If the organization's products have all three components built in, the more ready the organization would be to implement Industry 4.0(Lichtblau et al., 2015; Porter & Heppelmann, 2015; M. Sony & Naik, 2019).

Table 3: Excerpts of respondents on smart products and services
"*Industry 4.0 implementation will be a success if the products of the organization are smart and has features such as self-configuration, self-diagnosis etc. If you are going to automate the organization and supply chain, what about the product? So, if the organizations existing products are smart, there is a high chance that the organization is ready for Industry 4.0. Suppose you are a motorcycle manufacturer, if your product is not smart, then an organization will not be able to harness the full potential of Industry 4.0. The same is the case with service, if you don't design services based on real-time data analytics, once cannot achieve the full potential of Industry 4.0*" **- P20**
"*One needs to understand the existing product portfolio, if your existing portfolio consists of smart products and services, then it is easier for organizations to migrate to Industry 4.0 compared to organizations whose products are not smart. The smart products offer a unique opportunity to tailor services based on the usage data. Industry 4.0 should improve the customer experience and satisfaction*" **- P36**
"*An Organization should have products which can transmit or share information about itself, environment and its users. Besides, it should be able to monitor and take actions if it notices any discrepancies while working*" **-P28**

Table 3: Excerpts of respondents on smart products and services
*"Imagine you are going to your favourite hotel and the room intelligently senses your presence, and adjust things like room temperature, digital channel contents of your TV, your favourite food is suggested and so on. Services in the modern world are changing with the advent of new technology" - **P21***

The three core elements of a smart service are real-time data collection, continuous communication and interactive feedback (Allmendinger & Lombreglia, 2005). The intelligent object of the smart service could be an individual customer (e.g., health monitoring), a group of customers (e.g., family home monitoring) or a firm (e.g., monitoring of industrial equipment). Organizations can make use of the information gathered through intelligent objects to improve their service offerings and let customers benefit from customized service features (Wünderlich et al., 2015). The extent to which the organization's service is smart will be an indicator, to understand how ready an organization is to implement Industry 4.0.

4.1.4 Digitalisation of Supply Chains

Digitalisation has encompassed not only smart products and services but also the handling of the supply chain (Nasiri et al., 2020). Supply chains are defined as a "series of interconnected activities that involve the coordination, planning and controlling of products and services between suppliers and customers" (Büyüközkan & Göçer, 2018). The traditional supply chain is made of a series of discrete siloed steps from supplier to consumer. The digitalisation of supply chains will result in breaking down the walls and transforming the supply chain into an integrated system that would run flawlessly. The digital supply chain could be defined as a "*bundle of interconnected activities that are involved in supply chain processes between the*

supplier and customers, which are handled with novel technologies"(Büyüközkan & Göçer, 2018).

Table 4: Excerpts of respondents on digitalization of supply chains
"*The supply chain is the key element for the success of any organization. If the supply chains are digitised it will result in better coordination, agility, transparency, it would be a demand-driven system, the cash flow will be increased due to faster supply chains and so on. If an organizations existing supply chain is digitised, it stands a better chance of being ready to implement Industry 4.0*" **- P24**
"*Digital supply chains are a remarkable phenomenon however most supply chains though digitalised in parts have not lived up to the expectation. The challenge for the implementation of Industry 4.0 is strategic digitisation of the supply chain using the three principles of Industry such as horizontal, vertical and end-to-end integration*." **-P27**
"*The technology has changed the supply chains from reducing transaction costs to innovation in production and distribution. The traditional supply chains which were linear have become now dynamic, agile, and responsive with the use of technology. Besides the transparency and coordination within the supply chains have improved a lot*" **-P10**
"*Supply chain digitization is not just automating one task, but rather a holistic transformation of the supply chain. It looks at the integration of different organizations in the supply chain using digital technologies and modelling it using digital twins*" **- P6**

The digital supply chain is built on both digital transformation and smart technologies. The role of digital technologies in the digital transformation of the supply chain is the key element and hence organizations need to improve the level of technical adaptability and implementation of digital technologies (Frank et al., 2019; Pramanik et al., 2019). Therefore, organizations whose supply chains are digitalised stand a better chance of being ready to

implement Industry 4.0. The respondents in this study remarked on the importance of this and it is explicated in table 4.

4.1.5 Extent of the digital transformation of the organization

The digital transformation of an organization can be viewed as the degree of integration of digital technologies into all business areas of the organization (Verhoef et al., 2021). It fundamentally changes the way an organization carries out day to day business (Schwertner, 2017). It could be viewed as the usage of digital technologies to transform different functional departments and associated systems and processes within these functions of organizations such as production, purchasing, marketing, accounting, HR, and finance etc (M Sony & Aithal, 2020a). The three phases of the digital transformation of the organization are digitization, digitalization, and digital transformation (Verhoef et al., 2021).

Table 5: Excerpts of respondents on the digital transformation of the organization
"One needs to understand the present state of the organization in terms of the use of digital technologies. If the organization has just started using digital technologies without any changes to the way it does business, then the initiative may not be a success." - **P18**
"*There is a high chance of readiness for an organization to implement Industry 4.0 if all departments within an organization are integrated using the digital medium. This will help in planning, organising, controlling, leading, and coordinating various activities within an organization"* - **P14**
"*Digital connectivity of an organization will determine how ready an organization is to implement Industry 4.0. If only a few activities in the organization is done digitally, such organizations will have a lot of work to do before the implementation of Industry 4.0*" - **P35**

Table 5: Excerpts of respondents on the digital transformation of the organization
"*Most organizations have some degree of automation in their production lines and other departments are digitally connected. But there is no flow of information and information is still regulated by the relevant departmental heads. Such organizations are still in the primary phase and it will require some effort before they can conceive and implement Industry 4.0*" - **P34**

Digitization is transforming analogue data of an organization into a digital format and transmitting such information (Loebbecke & Picot, 2015). Digitalization is the use of ICT to alter existing business processes (Li et al., 2016). This results in new socio-technical organization structures with digital artefacts. The focus of digitalization of the organization is to improve business processes to improve the customer experience (Verhoef et al., 2021). Digital transformation describes organization-wide new thinking which results in new business models. It introduces a new business model by implementing new business logic to create and capture value (Pagani & Pardo, 2017). The digital transformation of an organization impacts the whole organization rather than changing simple organizational processes or tasks. The extent to which an organization is digitally transformed will determine how ready an organization is to implement Industry 4.0. The excerpts of the respondents are given in table 5.

4.1.6 Readiness of Industry 4.0 Organization strategy

Industry 4.0 can be thought of as a digital container filled with many technologies, principles, and management systems (Chiarini et al., 2020). At times organizations are disoriented when implementing Industry 4.0. Thus, for Industry 4.0 to be successful organizations must devise the strategy and deploy technologies, principles, and systems to strategically achieve them.

Another challenge for Industry 4.0 implementation is the lack of an implementation model or road map (Chiarini et al., 2020).

Table 6: Excerpts of respondents on the readiness of organization strategy
"*An organization should define the Industry 4.0 implementation strategy in terms of the customers, marketplace, their core competencies, competitors and their weaknesses. Industry 4.0 is not just technology implementation rather using technology strategically to achieve organizational goals and objectives*". **-P27**
"*There should be a plan for converting implementation of Industry 4.0 to a long-term competitive advantage. It is not just a short-term thing. We need to understand one thing that implementation of Industry 4.0 will lead to new customers, employees with new skills, a new relationship with society and so on. Therefore, an organization needs to understand the importance of strategy for the success of Industry 4.0*" **-P24**
"*Industry 4.0 implementation means an organization will have a huge amount of data. What an organization does with the data is most important. The organization should have a strategy to use the data and convert it to a unique business opportunity which will create a competitive advantage for the organization in long term*" **- P23**

Industry 4.0 implementation changes the long term relationship in terms of a) organization and nature (in terms of resource efficiency and sustainability in manufacturing systems) b) Organization and local communities (increased integration of customers in the design process, reach of wider customer base etc) c) organization and value chains (enabling mass customisation due to distributed and responsive manufacturing and collaborative processes) and d) Organizations and humans (in terms of improved human-machine interfaces and work conditions) (Santos et al., 2017; Michael Sony & Naik, 2019a). Another point to consider while designing the organizational strategy is the use of big data for competitive advantage

(M. Sony & Naik, 2019). Thus, the readiness of organization strategy to implement Industry 4.0 must consider these factors while implementing Industry 4.0. The excerpts of the respondents are given in table 6.

4.1.7 Innovative Industry 4.0 Business Model

Though there has been a large number of studies on technological aspects of Industry 4.0 (Weking et al., 2020), studies have also shown that businesses are struggling with profit after implementation of new technologies without a proper business model (Abdelkafi et al., 2013). Not only is product and service innovation important, but also innovation in the business model which will help to translate the same into profits (Weking et al., 2020). "*A mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model*" (Chesbrough, 2010).

Table 7: Excerpts of respondents on innovative Industry 4.0 Business Model
"*Industry 4.0 implementation is not just technology, rather it is using concepts such as crowdsourcing, personalisation, servitization, IoT in their business models. Just by implementing IoTs or CPS in the organization will not change anything rather organizations should translate these technologies into a business model which will help other organizations*" - **P17**
"*There is a huge opportunity for the organizations to use the advanced technologies of Industry 4.0 across their entire value chains, processes by using technology-mediated operational excellence, finding new business growth areas using technology, and incorporating technological breakthrough in manner employees, customers and other stakeholders create value. The strong business model will the organizations to succeed in the marketplace*." - **P23**

> *"Industry 4.0 business models need to be simple and answer the question; how the organization will provide products and service which the customer wants, and, in a manner, they want? Therefore, if an organization does not play with the existing business model, no way it can create success."* **- P37**

Manufacturers do not know or understand Industry 4.0 business models (Sarvari et al., 2018) or they are not able to change the traditional business to Industry 4.0 requirements (Weking et al., 2020). One of the reasons why firms are not able to transform the existing business models is because they do not understand their existing business models (Johnson et al., 2008). It is not only imperative that technology is deployed in an organization rather we need to customise the business models which will help the organization to grow. An organization that has a business model which can translate the technology to business ideas will thrive in the marketplace. Hence a technology ready business model will be a readiness factor for Industry 4.0 implementation. The excerpts of the respondents are given in table 7.

4.1.8 Leadership & Top Management Support for Industry 4.0

Industry 4.0 implementation calls for the digital transformation of the organization (Verhoef et al., 2021). Leadership will be the most important aspect in guiding the organization firstly in the digital transformation process and later in leading the organization in the digital environment (Sony, M. & Aithal, P.S., 2020). The leadership characteristics which a leader should possess would be a) visionary, b) networking intelligence, 3) adaptable, 4) motivating coach, 5) digital intelligence, 6) complexity master, 7) social intelligence, 8) democratic delegative, 9) agile, 10) learning from errors, 11) role model, 12) diversity champion, 13) decisive courageous, 14) creativity, 15) openness, 16) self-awareness, 17) ambidexterity, 18)

knowledge-oriented, 19) digital talent scout, 20) employee-oriented, 21) business intelligence, 22) lifelong learner, 23) ethical (Klein, 2020).

Table 8: Excerpts of respondents on leadership & top management support
"*The leader will be the most important person while implementing Industry 4.0 because he would be someone whom everyone will be looking up to. So, I suggest organizations who have a visionary and strong leader will be ready to implement Industry 4.0."* **- P4**
"*Strong visionary leaders will drive the organization towards successful implementation of Industry 4.0. It will face stiff implementation hurdles from stakeholders, and only strong leader will be able to instil the vision of big picture*". **-P11**
"*I can't say what type of leadership style will be best for implementation of Industry 4.0, rather I would say a leader with a strong vision towards Industry 4.0, integrity, ability to motivate employees and others to embrace Industry 4.0, somebody who acts as per the situation will be a good leader for the digital transformation*". **-P32**
"*A leader in this era should motivate the employees to unlearn and relearn. This is going to be a major challenge, especially in developed countries where you have a mature workforce. If the organization wants to sustain the competitive advantage, then the leader should be able to take swift decisions, be agile, be a coach for the employees and above all a guide through the implementation of Industry 4.0 as well after that"* **-P15**

Industry 4.0 is a radical change initiative because there would drastic reengineering of business processes, supply chains, strategies, business plans etc (de Sousa Jabbour et al., 2018; Michael Sony & Aithal, 2020). The leader would be the most important person who will guide the change within the organization as a change leader (By, 2020). Industry 4.0 implementation will lead to reorganization of existing work and therefore, the employees would be reorganized, retrained and reallocated (Bonekamp & Sure, 2015). A strong leader

will lead the employees and other stakeholders in a goal-directed manner to meet the objectives of the organization. In addition, another aspect is the top management support not only in terms of resource allocation, but also understanding the strategic importance of Industry 4.0 and taking tactical decisions for the successful implementation of Industry 4.0 (Sony, M. & Aithal, P.S., 2020). Furthermore, top management support can help to get necessary resources such as facility, capital, IT, and human resources. The excerpts of the respondents are given in table 8.

4.1.9 Organizational culture

Organizational culture is defined as " *the pattern of values, norms, beliefs, attitudes and assumptions that may not have been articulated but that shape how people in organizations behave and things get done. It can be expressed through the medium of a prevailing management style in the organization*" (Armstrong & Stephens, 2005). An innovative organizational culture will help an organization to transition towards Industry 4.0 implementation because having such a culture instils in the organization an environment that will encourage risky behaviour, an environment that will support new work behaviour, accepts new challenges and supports creative work (Ziaei Nafchi & Mohelská, 2020).

Table 9: Excerpts of respondents on organizational culture
"An organization which promotes creativity does not reprimand employees for thinking out of the box even if they fail to solve the problem. It is a supportive environment which will enable employees to find new solutions. Such organizations will create an environment which will help employees to innovate for every problem rather than using the same solutions" **-P17**
"An organization which is open, flat and has few hierarchies, with everyone encouraging new ways to solve an issue at work will be able to transition to Industry 4.0 more quickly

than others. This is because one can share ideas immediately without having to go through hierarchies and it will create a culture of cooperation and innovation" **-P26**
"*To bring in disruptive smart products and services, we need organizations who will encourage innovation. It should be in the DNA of the organization to be innovative and think of new ways for making products and services which will benefit the organization*" .**P11**

Most of the trivial and routine jobs would be done by machines in the Industry 4.0 era and jobs which require higher-order thinking will be left for humans (Sony, M. & Aithal, P.S., 2020),[45],[75]. Organizational culture will have a significant impact on creativity and innovation. Employees who are creative and innovative will be more effective if the organizational culture supports them (Shanker et al., 2017). An innovative culture in an organization supports and encourages creative work, and it will further enable one to face new challenges (Ziaei Nafchi & Mohelská, 2020). The excerpts of the respondents are given in table 9.

4.1.10 Employee Reward and Recognition System

People have basic needs and if these needs are not met then it becomes difficult for them to advance in their occupations. Besides, meeting their personal needs helps them to self-actualize which can further motivate them to improve their performance (Marshall et al., 2015). Industry 4.0 is a socio-technical system wherein social (human) and technical factors come together in a goal-directed manner to meet the objectives of the organization (Davies et al., 2017; M. Sony & Naik, 2020). Therefore, a reward and recognition system while

implementing Industry 4.0 will bring out the best in human elements which will help organizations (Aithal & Sony, 2020). The excerpts of respondents are given in table 10.

Table 10: Excerpts of respondents on employee reward systems and recognition
"*Organizations should have both monetary and non-monetary reward systems which will help the employees to remain motivated while implementing different facets of Industry 4.0. Industry 4.0 implementation is a complex task, and the organizations should motivate the employees by rewarding and recognising their achievements. It will help them sustain their performance and others will be motivated to perform better*" **-P20**
"*Recognising employees who have shown willingness to work hard while implementing Industry 4.0 will help them to be motivated to sustain their efforts as Industry 4.0 is a long journey. The employee motivation levels should be very high and hence recognition will go a long way in sustaining it*" **-P14**

4.2 Quantitative Study Results: Ranking of Industry 4.0 readiness Dimensions

Industry 4.0 readiness factors were examined for both manufacturing and service organizations. The ten Industry 4.0 readiness factors were ranked based on the mean scores and are depicted in tables 11 and 12. To determine the exact criticality of the readiness factor, a methodology suggested by Adabre et al (2019) was followed. The mean score was normalised. The readiness factors whose normalised scores above 0.5 were considered to be critical readiness factors. Normalised value = (mean – minimum mean)/(maximum mean - minimum mean). The normalised scores greater than 0.5 is considered as critical readiness factor (Adabre & Chan, 2019; Osei-Kyei & Chan, 2017). The ranking for the manufacturing sector

Table 11: Ranking of the manufacturing sector			
Readiness factor dimensions	**Manf**	**Normalisation**	**Rank**
Technology Readiness	6.22	1	1
Readiness of Industry 4.0 Organization strategy	5.59	0.72	2
Organizational culture	5.12	0.51	3
Leadership & Top Management Support for Industry 4.0	5.07	0.48	4
Digitalisation of Supply Chains	4.83	0.38	5
Innovative Industry 4.0 Business Model	4.78	0.36	6
Employee Adaptability with Industry 4.0	4.41	0.19	7
Extent of digital transformation of organization	4.21	0.10	8
Employee Reward and Recognition	4.12	0.06	9
Smart Products and Services	3.97	0	10

In the manufacturing sector, the most critical readiness factors were technology readiness, the readiness of Industry 4.0 organizational strategy and Organizational culture. The integration of CPS with production, logistics and other related functions of production will transform the modern organization into an Industry 4.0 factory (Lee et al., 2015), hence the technological readiness of the organization to adapt and apply the technology in the organization is very important for the successful implementation of Industry 4.0.

In the service sector, the most critical readiness factors were employee adaptability with Industry 4.0, technology readiness, organizational culture, and an innovative business model. The ranking of critical success factors in service sectors is given in table 12. The simultaneous production-consumption nature of service warrants employees to be the key

element in delivering the service (Parasuraman et al., 1985; M Sony & Mekoth, 2012) therefore employee adaptability with Industry 4.0 is important for its success.

Table 12: Ranking in the Service Sector

Readiness factor dimensions	**Service**	**Normalisation**	**Rank**
Employee Adaptability with Industry 4.0	6.21	1	1
Technology Readiness	5.72	0.79	2
Organizational culture	5.27	0.60	3
Innovative Industry 4.0 Business Model	5.14	0.54	4
Leadership and Top Management Support for Industry 4.0	5.07	0.51	5
Employee Reward and Recognition	4.86	0.42	6
Readiness of Industry 4.0 Organization strategy	4.83	0.40	7
Extent of digital transformation of organization	4.79	0.39	8
Smart Products and Services	4.31	0.18	9
Digitalisation of Supply Chains	3.90	0	10

The ranking for small and medium scale industries suggests technology readiness, the readiness of Industry 4.0 organizational strategy and organizational culture. Technology readiness is the highest-ranked critical Industry 4.0 readiness factor for both SMEs and LEs. The ranking of SMEs and LEs is explicated in table 13 and 14.

Table 13: Ranking of readiness factors in SMEs

Readiness factors	**SME (Mean scores)**	**Normalisation**	**Rank**
Technology Readiness	5.89	1	1

Readiness of Industry 4.0 Organization strategy	5.137	0.63	2
Organizational culture	4.89	0.51	3
Employee Adaptability with Industry 4.0	4.79	0.46	4
Leadership & Top Management Support for Industry 4.0	4.68	0.41	5
Innovative Industry 4.0 Business Model	4.44	0.3	6
Digitalisation of Supply Chains	4.20	0.18	7
Extent of digital transformation of organization	4.10	0.13	8
Employee Reward and Recognition	4.03	0.1	9
Smart Products and Services	3.82	0	10

In large enterprises, the ranking suggests technology readiness, employee adaptability with Industry 4.0, organizational culture, the readiness of organizational strategy, leadership and top management support, and an innovative Industry 4.0 business model as the very critical Industry 4.0 readiness factors.

Table 14: Ranking of readiness factors in LEs

Readiness factors	**LE (Mean Scores)**	**Normalisation**	**Rank**
Technology Readiness	6.09	1	1
Employee Adaptability with Industry 4.0	5.41	0.61	2
Organizational culture	5.39	0.60	3
Readiness of Industry 4.0 Organization	5.36	0.58	4

strategy			
Leadership & Top Management Support for Industry 4.0	5.34	0.57	5
Innovative Industry 4.0 Business Model	5.26	0.53	6
Extent of digital transformation of organization	4.70	0.21	7
Employee Reward and Recognition	4.70	0.21	8
Digitalisation of Supply Chains	4.60	0.16	9
Smart Products and Services	4.31	0	10

As the data is non-normal, nonparametric tests were used to test the difference in groups(Milenovic, 2011) of Industry 4.0 readiness factors in manufacturing and service sectors. The group difference was statistically different using Mann Whitney U Test P-Value and is explicated in table 15. Technology readiness, the readiness of Industry 4.0 organizational strategy and digitization of supply chains had higher mean scores compared to a service organization. This indicates in manufacturing these dimensions are very vital compared to services. It could be because there is tangibility of output in manufacturing, inventory, automated production etc(Chase et al., 1998), therefore technology, strategy and supply chain play a major role in manufacturing. However, employee adaptability with Industry 4.0, extent of digital transformation of the organization and employee reward and recognition the mean scores were higher for the service sector compared to manufacturing organizations. Services are labour intensive, simultaneous production consumption, service induced variability and hence employees are key in success of services(Allmendinger & Lombreglia, 2005; Chase et al., 1998; M Sony & Mekoth, 2012). Therefore, in service industry employee adaptability and reward & recognition were the key factors. Most of

manufacturing organizations are automated compared to services(Frohm et al., 2008; Parschau & Hauge, 2020), therefore, respondents felt that in service extent of digital transformation of organization is important compared to manufacturing.

Table 15: Mean score difference in Manufacturing and service

	Manf	**Service**	**Mann Whitney U Test P Value**
Technology Readiness	6.22	5.72	0.01**
Readiness of Industry 4.0 Organization strategy	5.59	4.83	0.00 **
Organizational culture	5.12	5.28	0.50
Leadership & Top Management Support for Industry 4.0	5.07	5.07	0.95
Digitalisation of Supply Chains	4.83	3.90	0.01**
Innovative Industry 4.0 Business Model	4.78	5.14	0.23
Employee Adaptability with Industry 4.0	4.41	6.21	0.00**
Extent of digital transformation of organization	4.22	4.79	0.046**
Employee Reward and Recognition	4.12	4.86	0.01**
Smart Products and Services	3.98	4.31	0.24

** Significant difference at 5%

Similarly, the testing for mean score of SME and LE explicated in table 16 suggest that organizational culture, leadership and top management support for Industry 4.0, innovative

Industry 4.0 business model, the extent of the digital transformation of the organization, and employee reward and recognition were higher for LE's and different statistically significant compared with SMEs.

Table 16: Mean score difference in SME's and LE's

Readiness factors	**SME (Mean)**	**LE (Mean)**	**Mann Whitney U Test P Value**
Technology Readiness	5.90	6.10	0.30
Readiness of Industry 4.0 Organization strategy	5.14	5.37	0.35
Organizational culture	4.90	5.39	0.01**
Leadership & Top Management Support for Industry 4.0	4.69	5.34	0.07
Digitalisation of Supply Chains	4.21	4.61	0.04 **
Innovative Industry 4.0 Business Model	4.45	5.27	0.00 **
Employee Adaptability with Industry 4.0	4.79	5.41	0.14
Extent of digital transformation of organization	4.10	4.71	0.04**
Employee Reward and Recognition	4.03	4.71	0.02 **
Smart Products and Services	3.83	4.32	0.10

** Significant difference at 5%

This could be because LE's tend to offer more products and services to a variety of customers compared to SME's who focus on niche markets(Nicholas et al., 2011; Perrini et al., 2007).

Therefore, LE's need an innovative business model, organizational culture and leadership &top management support. Besides, LE's has more than 250 employees(Ayandibu & Houghton, 2017) hence for such as large force to be motivated an organization needs employee reward and recognition system which is dynamic. LE's are large organizations and needs to be automated and digitalised for increased productivity and efficiency(Bessen et al., 2020; Craig & Noori, 1985) , therefore extent of digital transformation plays a major role as a readiness factor.

5. Implication for the organization

This study has uncovered ten dimensions of Industry 4.0 readiness model. Further it has discovered critical dimensions in manufacturing, service, SME and LE's. Organizations before implementing Industry 4.0 can use these dimensions to assess whether they are ready to implement Industry 4.0. Each of the dimensions can be used by the organizations to assess the current state. To cite an instance the organizational culture, organizations can conduct a self-assessment study to first understand whether their existing organizational culture is ready to implement Industry 4.0. This is can be done through a survey and also through focus group discussions. Subsequently, depending upon the present state, a future strategic and tactical plan may be devised so that organizations culture may be improved. Similarly, such an exercise can be done with other dimensions too. Also depending on the type of sector or size of the organization the importance of the weightage attached to these dimensions should vary as per the critical dimensions in the context of application. To cite an instance if the organization is a service organization and employee reward and recognition dimensions has a lower score. This is a cause of concern for service organizations and needs to be corrected on a priority compared to manufacturing organization. Therefore, this framework of readiness factors will help organizations as an investigative, readiness and sustenance tool for the successful implementation of Industry 4.0

6. Conclusion & Further work

The study proposed a conceptualisation of the readiness dimensions for Industry 4.0. Utilising qualitative methods, the study explored the ten dimensions of the Industry 4.0 readiness framework. Subsequently, the criticality of the dimensions in manufacturing, service, SMEs and LEs were found in the quantitative study. The difference in the dimensions in manufacturing and service and between SME's and LE's was also explored in this study. The limitation of the study is that the items are measured on a single-item scale. Since the sub-dimensions are homogenous constructs the single item scale was used for simplicity. However, a future study can explore the same topic as a multidimensional item scale. Another study would be longitudinal analysis of the dimension pre, during and post-implementation of Industry 4.0 to understand the time-oriented behaviour of Industry 4.0 readiness models. The authors are carrying out case studies wherein this model will be used to assess Industry 4.0 readiness and study the efficacy of the model in predicting the successful implementation of Industry 4.0.

References

Abdelkafi, N., Makhotin, S., & Posselt, T. (2013). Business model innovations for electric mobility—What can be learned from existing business model patterns? *International Journal of Innovation Management*, *17*(01), 1340003.

Acioli, C., Scavarda, A., & Reis, A. (2021). Applying Industry 4.0 technologies in the COVID–19 sustainable chains. *International Journal of Productivity and Performance Management*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/IJPPM-03-2020-0137

Adabre, M. A., & Chan, A. P. C. (2019). Critical success factors (CSFs) for sustainable affordable housing. *Building and Environment*, *156*, 203–214.

Aithal, P. S., & Sony, M. (2020). Design of'Industry 4.0 readiness model'for Indian Engineering Industry: Empirical Validation Using Grounded Theory Methodology. *International Journal of Applied Engineering and Management Letters (IJAEML)*, *4*(2), 124–137.

Allen, I. E., & Seaman, C. A. (2007). Likert scales and data analyses. *Quality Progress*, *40*(7), 64–65.

Allmendinger, G., & Lombreglia, R. (2005). Four strategies for the age of smart services. *Harvard Business Review*, *83*(10), 131.

Antony, J, & Sony, M. (2021). An Empirical Study Into Qualifications and Skills of Quality Management Practitioners in Contemporary Organizations: Results From a Global Survey and Agenda for Future Research. *IEEE Transactions on Engineering Management*, 1–17. https://doi.org/10.1109/TEM.2021.3050460

Antony, Jiju, Sony, M., Dempsey, M., Brennan, A., Farrington, T., & Cudney, E. A. (2019). An evaluation into the limitations and emerging trends of Six Sigma: An empirical study. *The TQM Journal*, *31*(2), 205–221.

Antony, Jiju, Sony, M., & Gutierrez, L. (2020). An Empirical Study Into the Limitations and Emerging Trends of Six Sigma: Findings From a Global Survey. *IEEE Transactions on Engineering Management*. https://doi.org/10.1109/TEM.2020.2995168

Armstrong, M., & Stephens, T. (2005). *A handbook of management and leadership: A guide to managing for results*. Kogan Page Publishers.

Avis, J. (2018). Socio-technical imaginary of the fourth industrial revolution and its implications for vocational education and training: A literature review. *Journal of Vocational Education & Training*, *70*(3), 337–363.

Ayandibu, A. O., & Houghton, J. (2017). The role of Small and Medium Scale Enterprise in local economic development (LED). *Journal of Business and Retail Management Research*, *11*(2).

Bag, S., Gupta, S., & Kumar, S. (2021). Industry 4.0 adoption and 10R advance manufacturing capabilities for sustainable development. *International Journal of Production Economics*, *231*, 107844.

Bessen, J., Goos, M., Salomons, A., & van den Berge, W. (2020). *Automation: A Guide for Policymakers*.

Bonekamp, L., & Sure, M. (2015). Consequences of Industry 4.0 on human labour and work organisation. *Journal of Business and Media Psychology*, *6*(1), 33–40.

Botha, A. P. (2018). Rapidly arriving futures: Future readiness for Industry 4.0. *South African Journal of Industrial Engineering*, *29*(3), 148–160.

Bree, R. T., & Gallagher, G. (2016). Using Microsoft Excel to code and thematically analyse qualitative data: A simple, cost-effective approach. *All Ireland Journal of Higher Education*, *8*(2).

Brozzi, R., D'Amico, R. D., Monizza, G. P., Marcher, C., Riedl, M., & Matt, D. (2018). Design of Self-assessment Tools to measure industry 4.0 readiness. A methodological approach for craftsmanship SMEs. *IFIP International Conference on Product Lifecycle Management*, 566–578.

Büyüközkan, G., & Göçer, F. (2018). Digital supply chain: Literature review and a proposed framework for future research. *Computers in Industry*, *97*, 157–177.

By, R. T. (2020). *Organizational change and leadership: Out of the quagmire*. Taylor & Francis.

Byrne, J., & Humble, A. M. (2007). An introduction to mixed method research. *Atlantic Research Centre for Family-Work Issues*, 1–4.

Caiado, R. G. G., Scavarda, L. F., Gavião, L. O., Ivson, P., de Mattos Nascimento, D. L., & Garza-Reyes, J. A. (2021). A fuzzy rule-based industry 4.0 maturity model for operations and supply chain management. *International Journal of Production Economics*, *231*, 107883.

Cameron, R. (2009). A sequential mixed model research design: Design, analytical and display issues. *International Journal of Multiple Research Approaches*, *3*(2), 140–152.

Charmaz, K., & Belgrave, L. L. (2007). Grounded theory. *The Blackwell Encyclopedia of Sociology*.

Chase, R. B., Aquilano, N. J., & Jacobs, F. R. (1998). *Production and operations management*. Irwin/McGraw-Hill,.

Chesbrough, H. (2010). Business model innovation: Opportunities and barriers. *Long Range Planning*, *43*(2–3), 354–363.

Chiarini, A., Belvedere, V., & Grando, A. (2020). Industry 4.0 strategies and technological developments. An exploratory research from Italian manufacturing companies. *Production Planning & Control*, *31*(16), 1385–1398.

Craig, R. G., & Noori, H. (1985). Recognition and use of automation: A comparison of small and large manufacturers. *Journal of Small Business & Entrepreneurship*, *3*(1), 37–44.

Creswell, J. W. (1999). Mixed-method research: Introduction and application. In *Handbook of educational policy* (pp. 455–472). Elsevier.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Davies, R., Coole, T., & Smith, A. (2017). Review of socio-technical considerations to ensure successful implementation of Industry 4.0. *Procedia Manufacturing*, *11*, 1288–1295.

Dawes, J. (2002). Five point vs. Eleven point scales: Does it make a difference to data characteristics. *Australasian Journal of Market Research*, *10*(1).

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Foropon, C., & Godinho Filho, M. (2018). When titans meet–Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors. *Technological Forecasting and Social Change*, *132*, 18–25.

Dworschak, B., & Zaiser, H. (2014). Competences for cyber-physical systems in manufacturing–first findings and scenarios. *Procedia CIRP*, *25*, 345–350.

Easterby-Smith, M., Thorpe, R., & Jackson, P. R. (2012). *Management research*. Sage.

Erol, S., Schumacher, A., & Sihn, W. (2016). Strategic guidance towards Industry 4.0–a three-stage process model. *International Conference on Competitive Manufacturing*, *9*, 495–501.

Felch, V., Asdecker, B., & Sucky, E. (2019a). *Maturity models in the age of Industry 4.0–Do the available models correspond to the needs of business practice?*

Felch, V., Asdecker, B., & Sucky, E. (2019b). *Maturity models in the age of Industry 4.0–Do the available models correspond to the needs of business practice?*

Fettig, K., Gačić, T., Köskal, A., Kühn, A., & Stuber, F. (2018). Impact of Industry 4.0 on Organizational Structures. *2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, 1–8.

Ford, M. R. (2009). *The lights in the tunnel: Automation, accelerating technology and the economy of the future*. Acculant Publishing.

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, *210*, 15–26.

Frohm, J., Lindström, V., Winroth, M., & Stahre, J. (2008). Levels of automation in manufacturing. *Ergonomia*.

Glaser, B. G., Strauss, A. L., & Strutzel, E. (1968). The Discovery of Grounded Theory; Strategies for Qualitative Research. *Nursing Research*, *17*(4), 364. https://doi.org/10.1097/00006199-196807000-00014

Gokalp, E., Şener, U., & Eren, P. E. (2017). Development of an Assessment Model for Industry 4.0: Industry 4.0-MM. *International Conference on Software Process Improvement and Capability Determination*, 128–142.

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods*, *18*(1), 59–82.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). Multivariate data analysis: Pearson new international edition. *Essex: Pearson Education Limited*.

Hastings, L., Sunderman, H., Hastings, M., McElravy, L. J., & Lusk, M. (2021). Leadership transfer in rural communities: A mixed methods investigation. *Community Development*, 1–29.

Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. *Procedia CIRP*, *54*, 1–6.

Hizam-Hanafiah, M., Soomro, M. A., & Abdullah, N. L. (2020a). Industry 4.0 Readiness Models: A Systematic Literature Review of Model Dimensions. *Information*, *11*(7), 364.

Hizam-Hanafiah, M., Soomro, M. A., & Abdullah, N. L. (2020b). Industry 4.0 Readiness Models: A Systematic Literature Review of Model Dimensions. *Information*, *11*(7), 364.

Johnson, M. W., Christensen, C. M., & Kagermann, H. (2008). Reinventing your business model. *Harvard Business Review*, *86*(12), 57–68.

Kinzel, H. (2017). Industry 4.0–Where does this leave the Human Factor? *Journal of Urban Culture Research*, *15*, 70–83.

Klein, M. (2020). Leadership characteristics in the era of digital transformation. *Business & Management Studies: An International Journal*, *8*(1), 883–902.

Krishnan, S., Gupta, S., Kaliyan, M., Kumar, V., & Garza-Reyes, J. A. (2021). Assessing the key enablers for Industry 4.0 adoption using MICMAC analysis: A case study. *International Journal of Productivity and Performance Management*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/IJPPM-02-2020-0053

Lee, Bagheri, B., & Kao, H.-A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing Letters*, *3*, 18–23.

Li, F., Nucciarelli, A., Roden, S., & Graham, G. (2016). How smart cities transform operations models: A new research agenda for operations management in the digital economy. *Production Planning & Control*, *27*(6), 514–528.

Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., Millack, A., Schmitt, K., Schmitz, E., & Schroter, M. (2015). Industrie 4.0-Readiness. *Impuls-Stiftung Des VDMA Aachen-Köln*, *52*(1), 1–77.

Loebbecke, C., & Picot, A. (2015). Reflections on societal and business model transformation arising from digitization and big data analytics: A research agenda. *The Journal of Strategic Information Systems*, *24*(3), 149–157.

Marshall, T., Mottier, E. M., & Lewis, R. A. (2015). Motivational factors and the hospitality industry: A case study examining the effects of changes in the working environment. *Journal of Business Case Studies (JBCS)*, *11*(3), 123–132.

Masood, T., & Sonntag, P. (2020). Industry 4.0: Adoption challenges and benefits for SMEs. *Computers in Industry*, *121*, 103261.

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

Meyer, D. Z., & Avery, L. M. (2009). Excel as a qualitative data analysis tool. *Field Methods*, *21*(1), 91–112.

Milenovic, Z. M. (2011). Application of Mann-Whitney U test in research of professional training of primary school teachers. *Metodicki Obzori*, *6*(1), 73–79.

Nasiri, M., Ukko, J., Saunila, M., & Rantala, T. (2020). Managing the digital supply chain: The role of smart technologies. *Technovation*, *96*, 102121.

Nicholas, J., Ledwith, A., & Perks, H. (2011). New product development best practice in SME and large organisations: Theory vs practice. *European Journal of Innovation Management*.

Nunnally, J. C. (1994). *Psychometric theory 3E*. Tata McGraw-hill education.

O'Regan, N., & Ghobadian, A. (2004). Testing the homogeneity of SMEs. *European Business Review*.

Osei-Kyei, R., & Chan, A. P. C. (2017). Developing a project success index for public–private partnership projects in developing countries. *Journal of Infrastructure Systems*, *23*(4), 4017028.

Pagani, M., & Pardo, C. (2017). The impact of digital technology on relationships in a business network. *Industrial Marketing Management*, *67*, 185–192.

Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1985). A conceptual model of service quality and its implications for future research. *The Journal of Marketing*, 41–50.

Parschau, C., & Hauge, J. (2020). Is automation stealing manufacturing jobs? Evidence from South Africa's apparel industry. *Geoforum*, *115*, 120–131.

Perrini, F., Russo, A., & Tencati, A. (2007). CSR strategies of SMEs and large firms. Evidence from Italy. *Journal of Business Ethics*, *74*(3), 285–300.

Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies. *Harvard Business Review*, *93*(10), 96–114.

Power, A. (2015). LinkedIn: Facebook for professionals? *British Journal of Midwifery*, *23*(3), 196–198.

Pramanik, H. S., Kirtania, M., & Pani, A. K. (2019). Essence of digital transformation—Manifestations at large financial institutions from North America. *Future Generation Computer Systems*, *95*, 323–343.

Rajnai, Z., & Kocsis, I. (2018). Assessing industry 4.0 readiness of enterprises. *2018 IEEE 16th World Symposium on Applied Machine Intelligence and Informatics (SAMI)*, 225–230.

Santos, C., Mehrsai, A., Barros, A. C., Araújo, M., & Ares, E. (2017). Towards Industry 4.0: An overview of European strategic roadmaps. *Procedia Manufacturing*, *13*, 972–979.

Sarvari, P. A., Ustundag, A., Cevikcan, E., Kaya, I., & Cebi, S. (2018). Technology roadmap for Industry 4.0. In *Industry 4.0: Managing the digital transformation* (pp. 95–103). Springer.

Schwertner, K. (2017). Digital transformation of business. *Trakia Journal of Sciences*, *15*(1), 388–393.

Shanker, R., Bhanugopan, R., Van der Heijden, B. I. J. M., & Farrell, M. (2017). Organizational climate for innovation and organizational performance: The mediating effect of innovative work behavior. *Journal of Vocational Behavior*, *100*, 67–77.

Sony, M, & Aithal, P. S. (2020a). A Resource-Based View and Institutional Theory-Based Analysis of Industry 4.0 Implementation in the Indian Engineering Industry. *International Journal of Management, Technology, and Social Sciences (*, *5*(2), 154–166.

Sony, M, & Aithal, P. S. (2020b). Developing an Industry 4.0 Readiness Model for Indian Engineering Industries. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, *5*(2), 141–153.

Sony, M. & Aithal, P.S. (2020). Practical Lessons for Engineers to adapt towards Industry 4.0. *International Journal of Case Studies in Business, IT, and Education*, *4*(2), 86–97. https://doi.org/10.5281/zenodo.4008814

Sony, M, & Mekoth, N. (2012). A typology for frontline employee adaptability to gain insights in service customisation: A viewpoint. *International Journal of Services And*, *12*(4), 490–508.

Sony, M., & Naik, S. (2019). Ten Lessons for managers while implementing Industry 4.0. *IEEE Engineering Management Review*, *47*(2), 45–52.

Sony, M., & Naik, S. (2020). Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model. *Technology in Society*, 101248.

Sony, Michael, Antony, J., & Douglas, J. A. (2020). Essential ingredients for the implementation of Quality 4.0: A narrative review of literature and future directions for research. In *TQM Journal* (Vol. 32, Issue 4). https://doi.org/10.1108/TQM-12-2019-0275

Sony, Michael, & Naik, S. (2019a). Key ingredients for evaluating Industry 4.0 readiness for organizations: A literature review. *Benchmarking: An International Journal*, *27*(7), 2213–2232. https://doi.org/10.1108/ BIJ-09-2018-0284

Sony, Michael, & Naik, S. (2019b). Key ingredients for evaluating Industry 4.0 readiness for organizations: A literature review. *Benchmarking: An International Journal*, *27*(7), 2213–2232. https://doi.org/10.1108/ BIJ-09-2018-0284

Stentoft, J., Adsbøll Wickstrøm, K., Philipsen, K., & Haug, A. (2020). Drivers and barriers for Industry 4.0 readiness and practice: Empirical evidence from small and medium-sized manufacturers. *Production Planning & Control*, 1–18.

Strauss, A., & Corbin, J. (1994a). Grounded theory methodology. *Handbook of Qualitative Research*, *17*(1), 273–285.

Strauss, A., & Corbin, J. (1994b). Grounded theory methodology. *Handbook of Qualitative Research*, *17*(1), 273–285.

Sullivan, G. M., & Artino Jr, A. R. (2013). Analyzing and interpreting data from Likert-type scales. *Journal of Graduate Medical Education*, *5*(4), 541.

Váně, J., Kalvas, F., & Basl, J. (2021). Engineering companies and their readiness for Industry 4.0. *International Journal of Productivity and Performance Management*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/IJPPM-06-2020-0318

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, *122*, 889–901.

Weking, J., Stöcker, M., Kowalkiewicz, M., Böhm, M., & Krcmar, H. (2020). Leveraging industry 4.0–A business model pattern framework. *International Journal of Production Economics*, *225*, 107588.

Weyer, S., Schmitt, M., Ohmer, M., & Gorecky, D. (2015). Towards Industry 4.0-Standardization as the crucial challenge for highly modular, multi-vendor production systems. *Ifac-Papersonline*, *48*(3), 579–584.

Wünderlich, N. V, Heinonen, K., Ostrom, A. L., Patricio, L., Sousa, R., Voss, C., & Lemmink, J. G. A. M. (2015). "Futurizing" smart service: Implications for service researchers and managers. *Journal of Services Marketing*.

Ziaei Nafchi, M., & Mohelská, H. (2020). Organizational Culture as an Indication of Readiness to Implement Industry 4.0. *Information*, *11*(3), 174.