A survey on the readiness of Industry 4.0 adoption in the manufacturing sectors

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Abstract

In developed countries, the majority of manufacturing companies are moving to Industry 4.0 to stay competitive. But as far as concerning the developing countries there should be need of proper knowledge about the Industry 4.0. The findings of the survey are presented in this article for evaluating the readiness of manufacturing industries in Indian perspective to adopt Industry 4.0 innovations. Also, readiness factors were validated based on the benefits realized by manufacturing industries as a result of implementing Industry 4.0 technologies through the development of hypotheses. Besides, this survey is the first to examine Industry 4.0 adoption status in Indian manufacturing industries. According to the findings, readiness factors have a significant relationship with the benefits achieved through the implementation of Industry 4.0, and research agenda for the future are discussed.

Introduction

Increasing uncertainties in today's global market have forced numerous manufacturing industries to introduce innovative production techniques to improve the productivity, profitability, and competitiveness of industries. The Industry 4.0 concept has been considered by manufacturing industries as a new dimension and many of them have implemented it in several various ways and titles. A tradition of continual improvement effort is important for an organization's success and survival. Industries need to re-evaluate their processes and ensure that they are reliable and optimized and follow the voice of the consumer (Sharma and Gidwani, 2019). The Industry 4.0 concept seeks to boost intelligent factory effectiveness and productivity through the application of innovative manufacturing processes and strategies. Smart manufacturing helps products, machinery, and technology to be interconnected, optimizes facilities, eliminates costs, and maximizes profits. In general, Industry 4.0 offered the opportunity of flexible mechanisms to dynamically modify production functions, offering high granularity and accuracy processes for self-decision and real-time operation and selection of equipment (Vaidya et al., 2018; Alcácer & Cruz-machado, 2019).

Industry 4.0 focuses mainly on creating a smart network for manufacturing focused on digitization and automation through which computers, machines, and goods communicate among one another without human intervention (Sokolov and Ivanov, 2015; Gilchrist, 2016). To grasp the consequences of the Industry 4.0 implementation, the literature lacks coordinated and closely oriented studies by practitioners and researchers (Hofmann and Rüsch, 2017; Almada-Lobo, 2016). Studies are required to establish a mock-up for the Industry 4.0 implementation and related new executive methods by analyzing various factors, benefits, implementation challenges, and hurdles to the Industry 4.0 implementation (Hermann et al., 2016). These studies will help in enhancing the awareness of Industry 4.0. Additionally, the consequence of Industry 4.0 is the emergence of smart industrial frameworks which involve smart goods, intelligent transportation, intelligent production, intelligent production systems, smart equipments, smart devices, smart suppliers, and so on (Shrouf et al., 2014; Schmidt et al., 2015; Li, 2018; Kamble et al., 2018a).

To succeed in today's increasingly diverse and aggressive market climate, digitization is also a must for supply chain processes (Pereira and Romero, 2017; Wu et al., 2016). Although, Ghobakhloo (2018), Sarvari et al. (2018) performed a study on Industry 4.0 transition process and roadmaps. But still, Industry 4.0 is not implemented absolutely in manufacturing industries of developing nations such as India. Nimawat and Gidwani (2021) delineate the various barriers towards the implementation of Industry 4.0. A successful primary focus for this technology transition is to recognize success factors, potential drivers, and barriers (Kamble et al., 2018b). Nosalska et al. (2019) suggested that the necessity of maturity frameworks and checking the readiness of manufacturing industries to adopt plans for digital change.

Nimawat and Gidwani (2020b), Abdirad and Krishnan (2020) indicated the limited quantity of researches has been carried out in the quantitative field, indicating that there is insufficient research focused on empirical findings. Wagire et al. (2019) suggested the need for examination of the consistency of theoretical frameworks through empirical analysis in various geographical regions. Nimawat and Gidwani (2020a), Nimawat and Gidwani (2020c) presented a lack of empirical research regarding verification of the status of Industry 4.0 adoption in developing nations. Hence there is a need to examine the level of awareness about the benefits of Industry 4.0 implementation and readiness about the industry 4.0 in manufacturing industries of developing nations.

This article is concerning a survey of the implementation of values of Industry 4.0 in Indian industries of manufacturing sector and the overall readiness of Indian manufacturing industries for such emerging phenomenon. Also to examine the significant relationship of readiness factors of Industry 4.0 implementation with the benefits achieved through the Industry 4.0 implementation.

The article's structure has been as follows: Sect. 2 offers readiness factors of Industry 4.0 implementation. Section 3 is concerned with the benefits achieved through the implementation of Industry 4.0. Section 4 delineates the adapted methodology to execute the present survey. Section 5 presents the statistical data analysis and findings obtained from the study's survey questionnaire. Section 6 deals with the conclusions of this survey. Finally, the future recommendations are proposed in Sect. 7.

Readiness Factors Of Industry 4.0 Implementation

To examine the readiness level of Industry 4.0 implementation in manufacturing industries, sixteen readiness factors were identified based on the key technologies of Industry 4.0 presented in Table 1, and also eleven benefits associated to Industry 4.0 adoption have been identified through an exhaustive literature review illustrated in Table 2.

Table 1
Identified sixteen readiness factors of Industry 4.0

Readiness factors of Industry 4.0	Authors
(RF01) Management motivation to incorporate emerging innovations	Young and Jordan, 2008; Dong et al., 2009; de Sousa Jabbour et al., 2018; Bauer et al., 2015; Palazzeschi et al., 2018; Thong et al., 1996
(RF02) Awareness of expected benefits	Müller et al., 2018; Schneider 2018; Kagermann et al. 2013; Müller et al., 2017; Theorin et al., 2017; Ooi et al. 2018; Kiel et al., 2017; Shrouf et al., 2014
(RF03) Customized solutions	Baldassarre et al., 2017; Witkowski, 2017; Gabriel and Pessl, 2016; Albers et al., 2016
(RF04) Competitive pressure	Kiel et al., 2017; Hecklau et al., 2016; Prahalad and Ramaswamy, 2004; Baldassarre et al., 2017
(RF05) Different individuals are able to access single integrated structure of complete visibility	Nimawat and Gidwani, 2020c; Müller et al., 2018; Jeschke et al., 2017
(RF06) IT specialist	Türkes et. al., 2019; Nimawat and Gidwani, 2020c
(RF07) Improvement in services and solution through consumer data inputs	Shrouf et al., 2014; Lasi et al., 2014; Heng, 2015; Seufert and Meier, 2016
(RF08) Real-time data available for decision-making	Hossain and Muhammad, 2016; Oesterreich and Teuteberg, 2016; Liu and Xu, 2017; Sanders et al., 2016
(RF09) Execution cost	Rennung et al., 2016; Erol et al., 2016; Porter and Heppelmann 2014; Theorin et al., 2017; Nicoletti, 2018; Arnold et al., 2016
(RF10) Training expenses and availability	Sackey et al., 2017; Sony and Naik, 2019
(RF11) Availability of machines and technologies as per Industry 4.0	Türkes et al., 2019; Nimawat and Gidwani, 2020c; Sevinc et al., 2018
(RF12) Digital vision on the basis of emerging demands of the market	Porter and Heppelmann, 2014; Gorecky et al., 2014
(RF13) Digital transformation leverages towards innovative product developments	Park and Huh, 2018; Brettel et al., 2017; Sanders et al., 2016; Monostori, 2014; Weyer et al., 2015; Frank et al., 2019a
(RF14) Utilization and collection of consumer information regularly with manufacturing industries	Yin et al., 2018; Kiel et al., 2017; Foidl and Felderer, 2015; Sader et al., 2019; Chiarini et al., 2020; Frank et al., 2019b; Lightfoot et al., 2013; Morrar et al., 2017
(RF15) Digital collaboration of all departments	Zawadzki and Żywicki, 2016; Nimawat and Gidwani, 2020c; Ghobakhloo, 2018; Hofmann and Rüsck, 2017
(RF16) Entire production data remotely accessed	Jeschke et al., 2017; Türkes et. al., 2019; Hossain and Muhammad, 2016

Table 2
Identified eleven Industry 4.0 benefits

Industry 4.0 benefits	Authors
(Benefit01) Improvement of product quality	Oesterreich and Teuteberg, 2016; Sommer, 2015; Kagermann et al., 2013; Ghadge et al., 2020
(Benefit02) Improve decision-making process	Kang et al., 2016; Veza et al., 2015; Müller et al., 2018
(Benefit03) Reduction of operational costs	Oesterreich and Teuteberg, 2016; Nunes et al., 2017; Zhou et al., 2017
(Benefit04) Increase in productivity	Schlechtendahl et al., 2015; Flammini et al., 2009; Paritala et al., 2016; Liao et al. 2017; Fatorachian & Kazemi 2018; Lasi et al., 2014
(Benefit05) Increase worker safety	Oesterreich and Teuteberg, 2016; Kamble et al., 2018a
(Benefit06) Improving sustainability	Ghadge et al., 2020; Stock and Seliger, 2016
(Benefit07) Increase of processes visualization and control	Wan et al., 2016; Lu and Cecil, 2016
(Benefit08) Reduction of product launch time	Müller et al., 2018; Oesterreich and Teuteberg, 2016
(Benefit09) Improvement of product customization	(Wang et al., 2016a; Wang et al., 2016b; Wang et al., 2016c)
(Benefit10) Optimize automation processes	Hofmann and Rüsck, 2017; Weyer et al., 2015; Liu and Xu, 2017
(Benefit11) Flexibility of business	Jazdi, 2014; Wan et al. , 2016; Liu and Xu, 2017; Weyer et al., 2015; Wang et al., 2016b; Li et al., 2017a; Li et al., 2017b

(RF01) Management motivation to incorporate emerging innovations

Top management dedication has been commonly accepted as essential to the management of transition (Young and Jordan, 2008). As the enterprise progresses, this relates to top management changing their message, attitudes, and encouragement and contributing themselves to certain activities that will produce the expected results (Dong et al., 2009). Top management is responsible for predicting corporate prospects to incorporate environmentally-

sustainable manufacturing into traditional manufacturing processes and Industry 4.0 innovations while playing a crucial responsibility in engaging in the transition of modern manufacturing (de Sousa Jabbour et al., 2018). For the emergence of Industry 4.0, technological advancement is critical but psychological tools are still very critical (Bauer et al., 2015). A key factor in the growth of Industry 4.0 will be the systematic handling of human resources (Palazzeschi et al., 2018). Engagement and dedication from the top management would serve as an incentive to support the new initiatives (Thong et al., 1996).

(RF02) Awareness of expected benefits

Industry 4.0 needs large expenditures with unpredictable returns (Müller et al., 2018); accelerated technical change renders these expenditures much riskier in terms of unclear benefits in the future (Schneider 2018; Kagermann et al. 2013). Industries remain confused and inexperienced with the phrase Industry 4.0 and are oblivious of the advantages of digital alteration because of this there is an unwillingness to implement it (Theorin et al., 2017; Müller et al., 2017). Industry 4.0 innovations are boosting profitability (Ooi et al. 2018; Kiel et al., 2017). Shrouf et al. (2014), taking into account the accepted benefits of Industry 4.0.

(RF03) Customized solutions

Interdependence, interaction, and prompt sharing of information enable organizations to implement creative systems to fulfill consumers' diverse demands (Baldassarre et al., 2017). Currently, manufacturing industries are centered on making an incentive for the client, who is turning out to be increasingly mindful and requesting concerning lead time to the deliverance of manufactured goods and manufactured goods accessibility, availability, and trustworthiness quality (Witkowski, 2017). A profound paradigm transition of Industry 4.0 is known to be the customization of goods, services, and manufacturing (Gabriel and Pessl, 2016). Albers et al. (2016) analyzed how Industry 4.0 technologies could affect industry performance; approximately half of those polled believed that by eliminate defective products and providing better quality, Industry 4.0 could dramatically raise consumer trust.

(RF04) Competitive pressure

Industries that implement Industry 4.0 technology boost their sector's competitiveness (Kiel et al., 2017). In order to remain competitive, firms have to deal with shortened launch time-to-market, reduced goods life - cycles, and the requirement of minimizing costs with an emerging modernization process (Hecklau et al., 2016). Modern customers have the flexibility to select from a range of goods and services; still, they appear to be disappointed. For this reason, it is also essential to produce customized goods to create demand, to survive on the market, to maintain or raise consumers (Prahalad and Ramaswamy, 2004; Baldassarre et al., 2017).

(RF05) Different individuals are able to access single integrated structure of complete visibility

Nimawat and Gidwani (2020c) suggested different individuals are able to access single integrated structure of complete visibility as an important factor for the Industry 4.0 adoption in manufacturing industries of developing nations. With the help of key technologies different individuals are able to access single integrated structure of complete visibility through the Industry 4.0 implementation (Müller et al., 2018; Jeschke et al., 2017).

(RF06) IT specialist

Handling key technologies of Industry 4.0 requires information technology experts (Türkes et al., 2019). Nimawat and Gidwani (2020c) suggested information technology specialists as an important factor for the adoption of Industry 4.0 in manufacturing industries of developing nations.

(RF07) Improvement in services and solution through consumer data inputs

Industry 4.0 helps industries to properly identify the behaviors and desires of consumers (Shrouf et al., 2014), and "the production of personalized goods in a batch amount of one can be realized while preserving the cost-effective requirements of mass creation" (Lasi et al., 2014). This is pointed to as mass customization, which encourages the design to have customer requirements and makes last-minute modifications (Shrouf et al., 2014; Heng, 2015). Seufert and Meier (2016) proposed that industries had to initially examine and define customer desires and expectations in order to effectively complete digital transformation. Those requirements can then be met by corresponding consumer-oriented improvements within the organization.

(RF08) Real-time data available for decision-making

Extra worth is made by optimization and decision-making among items and all manufacturing equipments and facilities in real-time for the better implementation of Industry 4.0 (Oesterreich and Teuteberg, 2016; Hossain and Muhammad, 2016). Industry 4.0 profoundly impacts the manufacturing situations with crucial alteration in the carrying out of activities by the means of allowing for real-time production planning and control, as contrasted with traditional predictive-based production planning (Sanders et al., 2016). The sharing and utilization of information in real-time by the components on a shop floor empowers a certain level of self-sufficiency, and additionally, progress towards autonomous production control and planning, which is an additional feature of Industry 4.0 (Liu and Xu, 2017).

(RF09) Execution cost

The execution of the Industry 4.0 concept has financial constraints concerning its high implementation cost for associated technologies and facilities (Rennung et al., 2016; Erol et al., 2016; Porter and Heppelmann 2014). In the implementation of Industry 4.0, financial restrictions are a major challenge with regard to the growth of advanced modern technology and the innovation of a sustainable process (Nicoletti, 2018; Theorin et al., 2017). The main focus that determines the amount of expenditure is the technological expertise of the target organization. The economic viewpoint, however, remains at a preliminary stage; this deficiency of clarification on the study of cost-benefit and financial returns on digital projects is a crucial problem for Industry 4.0 implementation (Arnold et al., 2016).

(RF10) Training expenses and availability

Sackey et al. (2017) want to deal with the effect of Industry 4.0 on an industrial engineering training educational plan by presenting a viable instructing and knowledge framework. In order to adapt CPS incorporation in an Industry 4.0 based intelligent factory, the employee needs to adapt to learning new IT skills and logical thinking ability. Employees need to adapt to emerging technology in a smart factory and to emerging ways of working (Sony and Naik, 2019).

(RF11) Availability of machines and technologies as per Industry 4.0

Sevinc et al. (2018), Nimawat and Gidwani (2020c), and Türkes et al. (2019) recommended the availability of technology and machines as per Industry 4.0 innovation is the most important enabling factor for the implementation.

(RF12) Digital vision on the basis of emerging demands of the market

Integration of digital facilities in items relies on IoT technology, smart processors, sensors, and programming-based software empowering novel abilities (Porter and Heppelmann, 2014). This is the current need to compete with the new market. Industry 4.0 incorporates high procedure digitalization and smart creation (Gorecky et al., 2014).

(RF13) Digital transformation leverages towards innovative product developments

Some of the Industry 4.0 pillars are digital computing assistance systems, digital manufacturing, human-robot cooperation, virtual training, and control and oversight support systems (Park and Huh, 2018). In the conditions of extremely flexible and modular manufacturing, advanced simulation tools for virtual prototyping, Internet of Services (IoS), and the IoT are seen as allowing customization (Brettel et al., 2017; Sanders et al., 2016; Monostori, 2014; Weyer et al., 2015). The digitization of manufacturing and the removal of distinctions between the real environment and the digital environment is another significant driver of support for Industry 4.0 (Frank et al., 2019a).

(RF14) Utilization and collection of consumer information regularly with manufacturing industries

Industry 4.0 gives industries the ability to learn directly through their clients (Kiel et al., 2017; Yin et al., 2018). Customer information and data are conveyed smoothly and effectively to the production department and processes in the era of Industry 4.0 (Foidl and Felderer, 2015; Chiarini et al., 2020; Sader et al., 2019) regarding specifications, basic dimensions, scheduling, and demands. CPS should support the notion that usefulness is not implicit in the quality of the manufactured goods but is perceived and measured by the user on the basis of benefit in operation and the sufficient smart goods to a broader concept of service advancement (Frank et al., 2019b; Lightfoot et al., 2013). In the same context, many researchers reported (Morrar et al., 2017) how Customer Relationship Management (CRM) would optimize technology parts such as machine learning, competitive intelligence, and social media, using customer relationships and expertise.

(RF15) Digital collaboration of all departments

Nimawat and Gidwani (2020c) suggested one of the enabling factors for Industry 4.0 adoption is cross-departmental digital cooperation.. Methods such as sophisticated scheduling methods, mass customization, and micro-segmentation enable industries to provide consumers with multi-choice products, efficiently accomplish the last-mile challenges with strong importance, deliver consumer orders at a quicker pace by implementing creative, digitized logistics and delivery procedures such as delivery by drones and beyond consumer requirements (Hofmann and Rüscher, 2017; Ghobakhloo, 2018; Zawadzki and Żywicki, 2016). This can be achieved through the digital collaboration of all departments.

(RF16) Entire production data remotely accessed

IIoT assists in remotely accessed overall production information (Hossain and Muhammad 2016). Through Industry 4.0 implementation provides the possibility to access all production information remotely with the help of internet services; this can minimize time delay in process execution (Jeschke et al., 2017; Türkes et al., 2019).

Benefits Achieved Through The Implementation Of Industry 4.0

Industry 4.0 concepts enhance product quality (Oesterreich and Teuteberg, 2016; Sommer, 2015; Kagermann et al., 2013). Industry 4.0 reflects a "modern paradigm" of manufacturing, leading to "quicker and also more efficient decision-making" (Kang et al., 2016) and an "entirely novel manufacturing strategy" (Veza et al., 2015). Smart goods are provided with algorithms capable of optimizing their processes, usage, and servicing (Oesterreich and Teuteberg, 2016; Nunes et al., 2017; Zhou et al., 2017). By utilization of high-grade digital technology for production information helps to optimize demand, reduce failure and improve productivity (Schlechtendahl et al., 2015; Flammini et al., 2009). Industry 4.0 innovations increase productivity (Liao et al. 2017; Fatorachian & Kazemi 2018). The flexibility provided by digital operations management provides workers with better workplace environments and a secure and safe manufacturing environmental condition (Kamble et al., 2018a). In the future, Industry 4.0's commitment to highly sustainable industrial value generation would be outstanding (Stock and Seliger, 2016). Not only between machines, but also between individuals, and between machines and humans, the endless collaboration and sharing of information (Wan et al., 2016). Industry 4.0 innovations aim to shorten product launch time (Oesterreich and Teuteberg 2016). "Digital technology allows for the manufacturing and services of the automatic and self-optimized products as well as distribution exclusive of manual involvement" (Hofmann and Rüscher, 2017).

The self-optimization of manufacturing networks including a number of parameters along with availability, costs (Weyer et al., 2015; Liu and Xu, 2017), and utilization of assets (Liu and Xu, 2017) is another reference point, which will support the economic component of sustainability and also the environmental component, potentially but less clearly. "Industry 4.0 provides a high degree of flexibility in the production, maintenance, and operation of automated

processes" (Jazdi, 2014). The emergence of applications for Industry 4.0 aims to minimize costs, increase productivity, efficiency, and adaptability, and increase customization of goods (Ghadge et al., 2020).

Making a reference to the Industry 4.0 economic viewpoint, transparency and process interconnection make it possible to optimize processes (Oesterreich and Teuteberg, 2016), rising quality, efficiency, productivity, flexibility, and customization (Peukert et al., 2015; Hossain and Muhammad, 2016; Kagermann et al., 2013). Improved demand orientation, new value proposals (Rehage et al., 2013), and smart manufacturing technologies (Lasi et al., 2014; Oettmeier and Hofmann, 2017) allowing for load balancing to enable them. Smart products (Stock and Seliger, 2016) are needed for this, which improves the competitiveness of a company (Porter and Heppelmann, 2014). Table 2 presents identified eleven benefits achieved through the adoption of Industry 4.0.

Methodology

The survey questions related to readiness factors and benefits of Industry 4.0 in this research are extracted from the literature review. The query for readiness and benefits arising from the literature review is the extent of readiness factors are fulfilled by manufacturing industries and according to which how much benefits they achieved. The survey problems are finally translated into hypotheses at this significant point. Initially, a reliability and validity test has been conducted. After that statistically descriptive data analysis has been carried out. Subsequently, the status of normality of survey data has been examined and found not normally distributed. Therefore, non-parametric tests as spearman's correlation test and chi-square test have been employed for analyzing the significant relationship of each readiness factor with all the Industry 4.0 benefits. The methodology of this research work is presented in Fig. 1.

Null and alternative hypotheses:

Ho1: Management motivation to incorporate emerging innovations has no significant association with Industry 4.0 benefits.

Ha1: Management motivation to incorporate emerging innovations has a significant association with Industry 4.0 benefits.

Ho2: Awareness of expected benefits has no significant association with Industry 4.0 benefits.

Ha2: Awareness of expected benefits has a significant association with Industry 4.0 benefits.

Ho3: Customized solution has no significant association with Industry 4.0 benefits.

Ha3: Customized solution has a significant association with Industry 4.0 benefits.

Ho4: Competitive pressure has no significant association with Industry 4.0 benefits.

Ha4: Competitive pressure has a significant association with Industry 4.0 benefits.

Ho5: Different individuals are able to access single integrated structure of complete visibility has no significant association with Industry 4.0 benefits.

Ha5: Different individuals are able to access single integrated structure of complete visibility has a significant association with Industry 4.0 benefits.

Ho6: IT specialist has no significant association with Industry 4.0 benefits.

Ha6: IT specialist has a significant association with Industry 4.0 benefits.

Ho7: Improvement in services and solution through consumer data inputs has no significant association with Industry 4.0 benefits.

Ha7: Improvement in services and solution through consumer data inputs has a significant association with Industry 4.0 benefits.

Ho8: Real-time data available for decision-making has no significant association with Industry 4.0 benefits.

Ha8: Real-time data available for decision-making has a significant association with Industry 4.0 benefits.

Ho9: Execution cost has no significant association with Industry 4.0 benefits.

Ha9: Execution cost has a significant association with Industry 4.0 benefits.

Ho10: Training expenses and availability has no significant association with Industry 4.0 benefits.

Ha10: Training expenses and availability has a significant association with Industry 4.0 benefits.

Ho11: Availability of machines and technologies as per Industry 4.0 has no significant association with Industry 4.0 benefits.

Ha11: Availability of machines and technologies as per Industry 4.0 has a significant association with Industry 4.0 benefits.

Ho12: Digital vision on the basis of emerging demands of the market has no significant relationship with Industry 4.0 benefits.

Ha12: Digital vision on the basis of emerging demands of the market has a significant association with Industry 4.0 benefits.

Ho13: Digital transformation leverages towards innovative product developments has no significant association with Industry 4.0 benefits.

Ha13: Digital transformation leverages towards innovative product developments has a significant association with Industry 4.0 benefits.

Ho14: Utilization and collection of consumer information regularly with manufacturing industries has no significant association with Industry 4.0 benefits.

Ha14: Utilization and collection of consumer information regularly with manufacturing industries has a significant association with Industry 4.0 benefits.

Ho15: The digital collaboration of all departments has no significant association with Industry 4.0 benefits.

Ha15: The digital collaboration of all departments has a significant association with Industry 4.0 benefits.

Ho16: Entire production data remotely accessed has no significant association with Industry 4.0 benefits.

Ha16: Entire production data remotely accessed has a significant association with Industry 4.0 benefits.

Statistical Data Analysis And Results

The research tool used was a questionnaire for the survey. The questionnaire is comprised of three elements. The first section inquired about the context of the respondents. The second section examined the understanding of their level of adoption of Industry 4.0 in their manufacturing industries and if they are dealing with the implementation of Industry 4.0, also asked about the benefits they achieved through the implementation of Industry 4.0 in the third section. The participants from different manufacturing industries that deal with Industry 4.0 concept were asked to evaluate two aspects (readiness factors and benefits) using a 5-point Likert scale. The readiness factors and benefits rating scales vary from: 1 - strongly disagree to 5 - strongly agree.

All queries were formed in a close-ended form in the survey questionnaire. On the basis of an exhaustive literature review, the survey questionnaire was formed.

The actual number of questionnaires collected was 175. Out of which 89 questionnaires collected were from the manufacturing industries (3-Micro Scale Industry, 3-Small Scale Industry, 20-Medium Scale Industry, and 63-Large Scale Industry) dealing with Industry 4.0 implementation. Hence, the total response rate was 16.18% (89/550).

Reliability and validity:

In the analysis, reliability and validity are crucial because it is necessary to ensure that the evidence obtained, evaluated, and interpreted is accurate and consistent in order to accomplish trustable outcomes (Saunders et al., 2009). By using a small number of respondents as a pilot sample before the delivery of the questionnaires to participants, Robson (2016) proposes a strategy for confirmation. The authors followed this approach. In this scenario, in line with the guidelines of Robson (2016), a target of 6 respondents was used for the pilot study, so the questionnaire was sent to 6 manufacturing industry professionals. Four risks to reliability are claimed by Robson (2016); participant bias, participant error, observer bias, and observer error.

This pilot study aimed to assure that, when interpreting and responding to the questions, the first two risks were resolved by avoiding inappropriate questions and contradictions. An opportunity had also been offered to provide suggestions on whether any extra questions were necessary to resolve the problem and to provide suggestions on the questionnaire's arrangement and linguistic aspects. As the questionnaire used specific optional questions that didn't need interpretation, the last two risks were not applicable. Some questions were corrected as a result of input from the pilot study to assure that participants had a similar understanding of the questions.

Reliability implies the consistency of the measure of the investigated survey (Field, 2011). Cronbach's alpha (α) is that the most often used to evaluate reliableness (Field, 2011). Cronbach's alpha (α) for both readiness factors and benefits is 0.972 which is very close to one, which cruels that the estimation (survey) is more reliable.

Descriptive statistics:

Table 3 provides the descriptive statistics on the readiness of the Industry 4.0 adoption among Indian manufacturing industries. The results show that the most important readiness factors of Industry 4.0 concepts fulfilled by the Indian manufacturing industries are: Management motivation to incorporate emerging innovations and Competitive pressure.

Table 3
Descriptive statistics of readiness factors
of the Industry 4.0 implementation

	N	Mean	Std. Deviation
RF01	89	4.07	1.095
RF02	89	3.93	1.175
RF03	89	3.91	1.062
RF04	89	4.00	1.087
RF05	89	3.75	1.131
RF06	89	3.91	1.083
RF07	89	3.89	1.201
RF08	89	3.80	1.179
RF09	89	3.98	1.158
RF10	89	3.80	1.089
RF11	89	3.81	1.065
RF12	89	3.94	1.132
RF13	89	3.78	1.085
RF14	89	3.67	1.064
RF15	89	3.78	1.095
RF16	89	3.65	1.109

Table 3: Descriptive statistics of readiness factors of the Industry 4.0 implementation

Table 4 provides the descriptive statistics on the benefits of the Industry 4.0 adoption among Indian manufacturing industries. The results show that the most important benefits achieved by the Indian manufacturing industries through Industry 4.0 concepts are: Increase in productivity, Improving sustainability, Improve decision-making process, Increase of processes visualization and control, Increase worker safety, and Optimize automation processes.

Table 4
Descriptive statistics of benefits achieved
through the implementation of Industry 4.0

	N	Mean	Std. Deviation
Benefit01	89	3.96	1.033
Benefit02	89	4.04	1.054
Benefit03	89	3.96	1.043
Benefit04	89	4.09	1.083
Benefit05	89	4.02	1.087
Benefit06	89	4.09	1.030
Benefit07	89	4.03	1.027
Benefit08	89	3.87	1.079
Benefit09	89	3.98	1.128
Benefit10	89	4.01	1.039
Benefit11	89	3.89	1.162

Table 4: Descriptive statistics of benefits achieved through the implementation of Industry 4.0

Specifically, for the readiness factors and benefits of the Industry 4.0 concept the Kolmogorov-Smirnov test and Shapiro-Wilk test presented in Table 5 and Table 6 delineates that responses do not align with the normal distribution. Therefore, for the investigation of the survey non-parametric tests (Spearman's correlation test and Chi-square test) have been utilized.

Table 5
Kolmogorov-Smirnov test and Shapiro-Wilk test for the readiness factors

	Kolmogorov-Smirnov ^(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
RF01	0.284	89	0.000	0.765	89	0.000
RF02	0.276	89	0.000	0.799	89	0.000
RF03	0.287	89	0.000	0.821	89	0.000
RF04	0.287	89	0.000	0.787	89	0.000
RF05	0.294	89	0.000	0.833	89	0.000
RF06	0.297	89	0.000	0.806	89	0.000
RF07	0.279	89	0.000	0.794	89	0.000
RF08	0.298	89	0.000	0.807	89	0.000
RF09	0.261	89	0.000	0.792	89	0.000
RF10	0.315	89	0.000	0.779	89	0.000
RF11	0.313	89	0.000	0.789	89	0.000
RF12	0.284	89	0.000	0.795	89	0.000
RF13	0.301	89	0.000	0.831	89	0.000
RF14	0.261	89	0.000	0.863	89	0.000
RF15	0.300	89	0.000	0.823	89	0.000
RF16	0.275	89	0.000	0.856	89	0.000

Table 6
Kolmogorov-Smirnov test and Shapiro-Wilk test for the benefits achieved through the implementation of Industry 4.0

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Benefit01	0.338	89	0.000	0.762	89	0.000
Benefit02	0.326	89	0.000	0.745	89	0.000
Benefit03	0.304	89	0.000	0.789	89	0.000
Benefit04	0.298	89	0.000	0.748	89	0.000
Benefit05	0.278	89	0.000	0.791	89	0.000
Benefit06	0.308	89	0.000	0.743	89	0.000
Benefit07	0.296	89	0.000	0.782	89	0.000
Benefit08	0.258	89	0.000	0.842	89	0.000
Benefit09	0.283	89	0.000	0.793	89	0.000
Benefit10	0.282	89	0.000	0.797	89	0.000
Benefit11	0.303	89	0.000	0.799	89	0.000

Table 5: Kolmogorov-Smirnov test and Shapiro-Wilk test for the readiness factors

Table 6: Kolmogorov-Smirnov test and Shapiro-Wilk test for the benefits achieved through the implementation of Industry 4.0

Hypothesis testing using chi-Square test and spearman's correlation test:

Using SPSS, the null-hypothesis test was carried out. The summary is presented in Table 7 indicates the outcomes of each questionnaire answer. The chi-square test results are shown in Table 7 and the p-value will be taken into consideration in particular. The chi-square test provides the researcher the opportunity to determine whether the obtained sequence could be taken into consideration as a random sequence within the data. A relation is then inferred between the two variables if the sequence is not random. The null hypotheses have been reported in this way in the methodology section. For example, the first is: Management willingness (first variable) has no significant relationship with the benefits achieved by the adoption of Industry 4.0 (second variable). To deny the null hypothesis, a 'p' value of less than 0.05 (5 percent) has been established; in this situation, the alternate hypothesis implies valid (Plackett, 1983). As a cut-off point, the test assumes a 5 percent value to reject the null hypothesis. This implies that there is a 5 percent chance of being no or wrong

relationship rather than a real relationship between two variables. The sixteen hypotheses exhibit the relationship of readiness factors of Industry 4.0 with Industry 4.0 benefits.

Table 7
Chi-square test for readiness factors and benefits of Industry 4.0

		Benefit01	Benefit02	Benefit03	Benefit04	Benefit05	Benefit06	Benefit07	Benefit08	Benefit09	Benefit10	Benefit11
RF01	χ^2	61.618	61.254	56.038	67.142	52.757	47.524	63.940	52.095	58.963	72.279	59.170
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF02	χ^2	58.682	67.336	45.836	74.827	37.736	41.965	52.656	53.701	51.128	66.959	49.889
	p-value	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF03	χ^2	61.718	66.152	66.243	83.214	99.239	77.316	97.856	48.957	78.970	98.547	87.517
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF04	χ^2	65.035	71.264	61.002	67.884	69.150	80.284	99.901	59.346	61.304	63.112	59.939
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF05	χ^2	89.330	74.201	64.617	66.808	55.241	61.761	70.327	41.397	48.120	45.734	55.390
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF06	χ^2	48.373	59.516	51.862	57.568	55.590	49.746	89.979	36.318	62.154	57.158	54.650
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF07	χ^2	65.272	59.394	56.127	62.816	54.903	63.834	84.217	53.902	77.734	66.831	73.767
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF08	χ^2	59.120	53.384	70.367	48.092	56.424	56.940	93.903	40.203	67.290	67.722	70.629
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF09	χ^2	56.301	64.068	53.769	61.690	44.277	39.727	59.588	47.423	48.291	62.429	50.707
	p-value	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF10	χ^2	44.305	49.612	46.388	64.633	43.018	48.031	56.540	46.653	47.393	45.190	43.491
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF11	χ^2	66.020	51.216	45.916	47.408	58.372	64.716	76.899	41.093	53.685	44.959	42.484
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF12	χ^2	41.507	48.175	32.501	59.659	42.248	47.360	54.101	50.435	35.984	45.146	36.581
	p-value	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.002
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF13	χ^2	53.288	46.496	67.026	56.309	41.598	49.756	47.202	62.877	52.719	45.270	55.432

		Benefit01	Benefit02	Benefit03	Benefit04	Benefit05	Benefit06	Benefit07	Benefit08	Benefit09	Benefit10	Benefit11
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF14	χ^2	49.942	45.507	53.319	53.017	75.677	59.991	59.310	55.676	55.610	48.214	51.019
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF15	χ^2	51.154	53.942	59.446	52.925	51.017	56.932	58.834	41.867	43.370	43.592	53.420
	p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject
RF16	χ^2	46.368	49.103	44.802	43.838	36.211	39.182	65.785	58.156	44.399	42.931	44.986
	p-value	0.000	0.000	0.000	0.000	0.003	0.001	0.000	0.000	0.000	0.000	0.000
	Decision	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject	H ₀ Reject

The outcome of Table 7 demonstrates that there is a significant relationship among all readiness factors of Industry 4.0 with the Industry 4.0 benefits.

Table 7: Chi-square test for readiness factors and benefits of Industry 4.0

Table 8: Spearman's correlation test for readiness factors and benefits of Industry 4.0

Table 8
Spearman's correlation test for readiness factors and benefits of Industry 4.0

	Benefit01	Benefit02	Benefit03	Benefit04	Benefit05	Benefit06	Benefit07	Benefit08	Benefit09	Benefit10	Benefit11
RF01	.556(**)	.508(**)	.551(**)	.582(**)	.470(**)	.462(**)	.465(**)	.408(**)	.491(**)	.550(**)	.462(**)
RF02	.472(**)	.480(**)	.444(**)	.492(**)	.468(**)	.491(**)	.532(**)	.382(**)	.495(**)	.518(**)	.474(**)
RF03	.424(**)	.428(**)	.349(**)	.398(**)	.365(**)	.364(**)	.372(**)	.339(**)	.408(**)	.493(**)	.488(**)
RF04	.481(**)	.500(**)	.445(**)	.453(**)	.432(**)	.404(**)	.418(**)	.362(**)	.291(**)	.329(**)	.284(**)
RF05	.552(**)	.535(**)	.563(**)	.573(**)	.544(**)	.578(**)	.527(**)	.291(**)	.441(**)	.459(**)	.519(**)
RF06	.481(**)	.573(**)	.578(**)	.543(**)	.458(**)	.462(**)	.587(**)	.374(**)	.361(**)	.442(**)	.400(**)
RF07	.420(**)	.451(**)	.420(**)	.437(**)	.459(**)	.506(**)	.547(**)	.341(**)	.472(**)	.468(**)	.457(**)
RF08	.540(**)	.512(**)	.478(**)	.469(**)	.437(**)	.529(**)	.528(**)	.321(**)	.470(**)	.523(**)	.526(**)
RF09	.516(**)	.479(**)	.511(**)	.528(**)	.441(**)	.420(**)	.447(**)	.364(**)	.432(**)	.521(**)	.415(**)
RF10	.375(**)	.478(**)	.450(**)	.545(**)	.466(**)	.475(**)	.511(**)	.239(*)	.344(**)	.323(**)	.418(**)
RF11	.423(**)	.535(**)	.538(**)	.483(**)	.517(**)	.510(**)	.540(**)	.336(**)	.380(**)	.394(**)	.339(**)
RF12	.348(**)	.399(**)	.340(**)	.451(**)	.413(**)	.436(**)	.427(**)	.304(**)	.354(**)	.322(**)	.375(**)
RF13	.394(**)	.373(**)	.417(**)	.480(**)	.453(**)	.471(**)	.405(**)	.339(**)	.426(**)	.454(**)	.480(**)
RF14	.472(**)	.476(**)	.500(**)	.563(**)	.597(**)	.627(**)	.498(**)	.385(**)	.520(**)	.456(**)	.470(**)
RF15	.451(**)	.521(**)	.511(**)	.496(**)	.509(**)	.481(**)	.470(**)	.338(**)	.397(**)	.452(**)	.443(**)
RF16	.434(**)	.550(**)	.426(**)	.393(**)	.368(**)	.443(**)	.472(**)	.413(**)	.453(**)	.496(**)	.376(**)
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

The spearman's correlation coefficients presented in Table 8 indicate that all readiness factors and all benefits are strongly positively correlated.

Furthermore, the outcome of the survey spearman's correlation test shows that all readiness factors of Industry 4.0 adoption have clear benefits in respect to manufacturing industries. The amount of benefits of manufacturing industries increases as the score of readiness factors of Industry 4.0 adoption increases. The findings thus support all results of the chi-square test and reject all sixteen null hypotheses.

Conclusions

Many industries claim that Industry 4.0 should be somewhat fresh, they don't have a strong idea about how they can execute this concept's adoption; however, they see the potential for significant change through emerging product implementation techniques and revolutionary technological developments.

As a result of the rejection of all null hypotheses using the chi-square test, the respondents acknowledge that in the manufacturing industries of developing countries, all readiness factors of Industry 4.0 have a significant association with the benefits of Industry 4.0. As a result of the above hypothetical findings, it was suggested that the industrial effectiveness related to all aspects of benefits-improved significantly after the adoption of Industry 4.0. These hypothetical findings demonstrate the utility for manufacturing industries that have not yet adopted Industry 4.0 but want to operate in a challenging manufacturing situation to maximize profits. In order to keep them viable in a challenging market companies should consider adopting Industry 4.0 technologies partially in the first stages, and fully implementing them later for maximizing profits. Therefore, it has also been concluded that stakeholders and administrators of manufacturing industries can verify the status of the Industry 4.0 concept with the help of the above stated sixteen readiness factors. And validation of the results of the chi-square test has been done through spearman's correlation test. Spearman's correlation test also delineates that all readiness factors have a significant relationship with all benefits of Industry 4.0.

This study indicates that the initiative to introduce this modern paradigm is in modest development, and in the future, the industries should see strong success and future promise of actual process and manufacturing results, and investment return, and market opportunities.

Future Scope

To advance this field, research has to be done to help manufacturing industries properly manage execution efforts by developing a statistical model and testing it on manufacturing industries interested in implementing Industry 4.0. Policymakers may conduct research using several case studies in order to generalize the findings. Future studies should look at specified sectors of manufacturing industries. This survey has been laid down in the Indian manufacturing environment (developing nation); the different environments such as from developed nations may provide some different results. Future research may also be conducted using more number of industries. Results may also be validated through the survey of other developing nations in the same context in future studies.

Declarations

Ethical Approval: Not applicable

Consent to Participate: Not applicable

Consent to Publish: Not applicable

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Figures

Figure 1

Methodology of this research work