Evaluation of Key Challenges to Industry 4.0 in Indian Context: A DEMATEL Approach

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Abstract The rapid development of information technology, analytics, computing capacity and hardware has led to increasing affinity towards the concept of Industry 4.0. Industry 4.0 uses cyber-physical systems (CPS), Industrial Internet of Things (IIoT) and cloud data sharing to develop intelligent manufacturing systems. The Indian industries under the patronage of national and local government initiatives like Make in India and Digital India are looking forwards to adopting best in class manufacturing infrastructure to support the changing industrial environment and utilize the immense opportunities ahead. For this purpose, Industry 4.0 will play a vital role in achieving manufacturing competitiveness. This paper is an attempt to evaluate the key challenges of Industry 4.0 in the Indian context. A decision-making trial and evaluation laboratory (DEMATEL) approach is used to establish relations between the key challenges.

Keywords Industry 4.0 · India · Challenges · DEMATEL · CPS · IIoT

1 Introduction

With the ever-changing economic scenario, India is again in the spotlight. It has been an IT stronghold of the world and now its manufacturing sector is on its way to another revolution labelled as 'Industry 4.0' [1]. Industry 4.0 is a highly efficient system of interconnected digital entities that work in coordination to help make intelligent decisions [2]. It majorly utilizes cyber-physical systems, information technology and smart devices. It can help transform Indian traditional plants into smart factories that can increase business gains. Decentralized control and self-learning are important factors [3]. Intelligent components are characterized by their ability to self-understand, communicate and implement information at every stage of the system. Decentralization of control aids by making the transition smoother with varying market demands. Customer requirements have also changed. This puts immense

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pressure on the industry to keep modifying their business models to stabilize competition. Majorly in India, a gap is seen between the application level and the factory level. Industry 4.0 can help bridge this gap.

Indian government has come up with initiatives like Green Energy Corridors, Make in India, Digital India and Skill India that aim to promote the use of renewable energy sources, in-house manufacturing, digitalization of industries by advanced technologies and training and education. According to IBEF, India has set a high target of achieving a 25% contribution from manufacturing sector of its gross domestic product (GDP) by the year 2025 [4]. This can be realized by adopting practices of Industry 4.0. In order to adopt Industry 4.0, the readiness of the industries must be checked. The manufacturing sector may face significant challenges in this process. This paper provides a summary of the key challenges that are/may be faced by industries.

The outline of the paper is: The research background of Industry 4.0, its components and key challenges are discussed in Sect. 2. Section 3 shows the application of DEMATEL approach on the case industry selected for research. After this, discussion of results is presented in Sect. 4 followed by concluding remarks in Sect. 5.

2 Research Background

2.1 Industry 4.0

Industry 4.0 was first seen as part of a German project. It can be defined as the application of computing and IT technologies to enhance the connectivity of the various sections of the industry. This connectivity enables integration between the elements of the entire supply chain, i.e. machinery, workers, suppliers and end customers. Industry 4.0 makes it possible to collect and examines the technical details from the machines to make the processes faster, flexible and efficient. This will lead to increase in industrial output and productivity. Industry 4.0 promotes collaboration among different plants of the company irrespective of the location. This is achieved by communication devices that are focussed on factors like reliability and longevity. Industry 4.0 creates a highly flexible and intelligent factory known as 'Smart Factory' [5]. For this, it has core components that enable its realization and sustenance.

2.2 Core Components of Industry 4.0

The main components of Industry 4.0 are cyber-physical systems (CPS), Industrial Internet of Things (IIoT) and cloud computing. Figure 1 shows the core components of Industry 4.0.

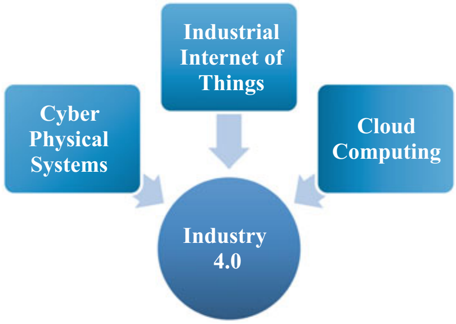


Fig. 1 Core components of Industry 4.0

Cyber-Physical Systems (CPS). CPS is a system that is driven by computer algorithms which have been integrated with Internet and its users. It combines the software (cyber components) and hardware (physical components) to generate an intense link [6]. CPS aims to ensure deep connectivity and real-time data collection between the physical entities of the factory. It also enables the analysis of the data to help make intelligent decisions [7]. A simple CPS comprises a control unit which actuates the physical components interacting with the real world and sensors that detect and process the data [8]. In order to reach the stature of Industry 4.0, there needs to be a specific approach, which is addressed by CPS by making the processes self-managed and autonomous.

Industrial Internet of Things (IIoT). IIoT is a literal upgrade of the Internet of Things (IoT), as in when IoT is applied to industries. IoT is the larger out of the two which aims at harnessing the power of Internet connectivity to improve business functions [9]. IIoT focusses on stronger requirements of manufacturing namely longevity of operation and safety of personnel [10]. IIoT utilizes machine learning to capture and communicate data [11]. This data can help identify issues sooner and practise better process control. It also provides better insight into the operational parameters of the industry, which leads to transformation of processes [12]. This accelerates productivity, thereby improving profits, which is thought behind Industry 4.0.

Cloud Computing. Cloud computing is an enabler of Industry 4.0. It offers storage and memory through the Internet as a service to the user. As buying physical storages is expensive, companies have switched to cloud computing. It offers high performance at lower cost. Cloud storage stores the communication between the machines as well as between machines and personnel. Cloud computing provides its users with an IT platform and resources for all needs. It relies on sharing of information both within and outside the organization. This helps organizations run their business faster and meet the demands of the market and customers at the earliest [13]. This nature of cloud computing makes it important for application of Industry 4.0.

2.3 Key Challenges to Industry 4.0

In order to adopt the Industry 4.0 in Indian industries, the major roadblocks to its implementation need to be identified. The following six key challenges have been found out from the extensive literature review and discussion with academicians.

Management Commitment (C1). Any major organizational change has to pass through the management, and the management's willingness is important [14]. Industry 4.0 brings a major change and is required to be backed up by the management. The major challenge in India is the lack of leadership as any change comes from the top down in an industry [1]. The leaders must be committed to the goal of Industry 4.0. They must be willing to re-analyse their organizational structure and maintain an enthusiastic work atmosphere in order to drive this industrial revolution.

High Investment and Future Viability (C2). Industry 4.0 brings with it high implementation cost. This high cost is attributed to machinery and equipment, training of personnel and consultancy services. For Indian industries, that is dominated by a large percentage of small-scale industries, this transformation may come at a cost of their market value [15]. Moreover, new entrants may acquaint themselves with industry models and threaten the existence of the prevalent players. As Industry 4.0 can both be a complicated and calculated risk, this change has uncertain future benefits and absence of benchmarking tools to evaluate accurate business gains.

Employee Fear and Resistance (C3). The pillars of any industry are its employees. The employees need to be provided with advanced training and education. As Industry 4.0 is computer oriented and relies on high reliability and accuracy, the unskilled workers stand at the risk of losing their jobs [16]. India has always faced issues with availability of skilled workers, labour unions and their management. The workers may be reluctant to be a part of such an organizational change [17]. The workers are not only required to improvise technical skills but also analytical decision making, in order to extensively use the new technologies.

Technical Fit and Integration of CPS (C4). The concept of Industry 4.0 revolves around CPS. The development of CPS in accordance with the existing facilities is a tedious job. It not only requires monetary support but dependence on external services. Indian Industries have been practising conservative ways for long enough. This makes generation and verification of a CPS model complicated. In order to benefit from Industry 4.0, the organizations must have proper methods of data collection and computation. This will require new visualizations and development of mathematical models and algorithms.

IT Security Concerns (C5). As IIoT involves interconnection of everything in an industry, it brings the risk of cybersecurity. The overall connectivity implies the use of more computers which will be burdensome to handle and control [18]. Any glitch in IT systems can be a setback for the organization. Moreover, a cyberattack can be devastating as it may cause a mark on the reputation of the company [19]. With increasing digitization of the assets, the security of the IT infrastructure is utmost important for the organization.

Lack of Government Support and Legal Issues (C6). The Indian government has come up in favour of Industry 4.0, but it lacks aggressiveness and supporting policies. It needs to promote the development of networking agencies that can help promote adoption of IIoT in industries. With the onset of new technologies, the government must promote cross-border trades to enhance technology sharing. On the other hand, strict laws regarding privacy protection must be enforced to avoid wrong handling of data. Legal regulations and compliances in regard to labour and safety management must be redesigned to aid adoption of Industry 4.0.

3 Application of DEMATEL and Case Example

This section discusses the DEMATEL approach and its application. For the analysis of the relationships between the key challenges, we have used decision-making trial and evaluation laboratory (DEMATEL) approach [20]. This technique was evolved by Battelle Memorial Institute, Geneva and is a structuring tool used to find out the cause and effect relationship among different factors. Other than finding out how the factors are connected; it also indicates the influence of the factors on the main system. The case example is a major automobile company with its strong presence in India. The study was subjected to its manufacturing facility in Delhi—NCR area. The respondents consisted of senior-level managers, production of charges, line managers and workers. The inputs were received in the form of pairwise comparisons (Table 1) between the identified challenges by brainstorming. The following are the steps of DEMATEL approach:

Table 1 Average (direct relation) matrix *A*

	C1	C2	C3	C4	C5	C6
C1	0	1.8	1.4	2.6	0.8	0.2
C2	3.5	0	2.2	3.2	1.7	0.6
C3	2.3	0.4	0	1.3	0.2	1.5
C4	3.4	2.3	2.1	0	2.6	0.4
C5	3.1	2.4	0.8	2.5	0	0.3
C6	3.7	2.8	2.3	1.6	2	0

3.1 Define Challenges and Evaluation Scale

The challenges have been described in Sect. 2. A total of six challenges are considered. The evaluation scale has numeric values ranging from ‘0’ to ‘4’, i.e. from low to high degree of influence/interrelation among the challenges.

3.2 Construct the Average (Direct Relation) Matrix

The responses have been obtained to form the inputs of the average matrix. The respondents have rated the influence of one challenge ‘i’ on another challenge ‘j’ based on the evaluation scale and filled a matrix of pairwise comparisons [21]. Let A $[i \times j]$ be the average matrix and k be the total respondents. The a_{ij} values of matrix A have been obtained by averaging the responses a_{ijk} of the k respondents for each comparison. Table 1 shows the average matrix A.

3.3 Calculate the Normalized Matrix B

Let B be the normalized matrix of the average matrix A. Calculate factor λ by using Eq. 1 which is as follows:

$$\lambda = \frac{1}{\text{Max}_{1 \le i \le n}\left(\sum_{j=1}^{n} a_{ij}\right)} \quad (1)$$

Matrix B as shown in Table 2 is calculated by using Eq. 2, i.e. multiplying matrix A by a factor λ,

$$B = A\lambda \quad (2)$$

Table 2 Normalized matrix B

	C1	C2	C3	C4	C5	C6
C1	0	0.15	0.11	0.21	0.06	0.02
C2	0.28	0	0.18	0.26	0.14	0.05
C3	0.19	0.03	0	0.10	0.02	0.12
C4	0.27	0.19	0.17	0	0.21	0.03
C5	0.25	0.19	0.06	0.20	0	0.02
C6	0.30	0.23	0.19	0.13	0.16	0

Table 3 Total relation matrix *C*

	C1	C2	C3	C4	C5	C6
C1	0.41	0.39	0.35	0.50	0.27	0.11
C2	0.84	0.39	0.52	0.70	0.43	0.18
C3	0.50	0.26	0.21	0.36	0.19	0.18
C4	0.81	0.53	0.50	0.47	0.47	0.16
C5	0.73	0.50	0.38	0.60	0.27	0.13
C6	0.93	0.63	0.57	0.66	0.48	0.15

3.4 Construct the Total-Relation Matrix C

The normalized matrix B can be transformed to total-relation matrix C as shown in Table 3 by using the Eq. 3,

$$C = B(I - B)^{-1} \tag{3}$$

where I = Identity Matrix.

3.5 Calculate the Challenge's Degree of Influence

The degree of influence of the challenges is attributed to the degree of prominence and degree of cause and effect. The values D and E are calculated by the Eqs. 4 and 5,

$$D = [d_{ij}]_{n\times 1} = \left[\sum_{j=1}^{n} c_{ij}\right]_{n\times 1} \tag{4}$$

$$E = [e_{ij}]_{1\times n} = \left[\sum_{i=1}^{n} c_{ij}\right]_{1\times n} \tag{5}$$

The prominence or correlation with others is given by $(D + E)$ and cause/effect is given by $(D - E)$ as shown in Table 4.

3.6 Construct the Cause–Effect and Prominence Graph

The prominence and cause/effect are shown in Figs. 2 and 3, respectively. They have been developed from values obtained in Table 4.

Table 4 Prominence and cause/effect values

	D	E	$D+E$	$D-E$
C1	2.02	4.22	6.24	−2.19
C2	3.06	2.70	5.76	0.36
C3	1.70	2.53	4.22	−0.83
C4	2.94	3.29	6.23	−0.35
C5	2.62	2.11	4.72	0.51
C6	3.41	0.90	4.31	2.51

Fig. 2 Prominence graph

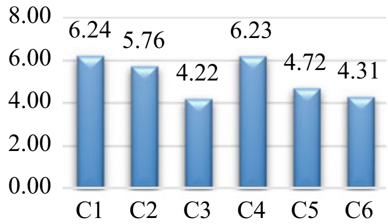
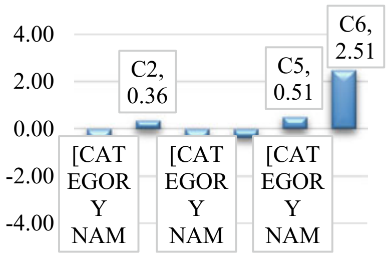


Fig. 3 Cause–effect graph



4 Results and Discussion

Table 4 shows the $D+E$ and $D-E$ values for the challenges. $D+E$ signifies the prominence or the extent of correlation with other challenges. In other words, to what degree the challenges influence each other. The challenge, management commitment (C1) has the highest prominence value of 6.24 followed by technical fit and integration of CPS (C4) with a value of 6.23. This shows that C1 and C4 have the most correlation or influence on the other challenges. On the other hand, challenge employee fear and resistance (C3) has the lowest prominence value of 4.22, showing its low influence on the other challenges as well as on the system. Therefore, prominence of C1 and C4 is quite high signifying that commitment of management and the technical feasibility of the CPS have a high impact on the behaviour and influence of other barriers. $D-E$ shows the values of cause and effect for the challenges. If $(D-E)$ is greater than zero (0), the challenge is categorized as a cause challenge while if $(D-E)$ is less than zero (0), the challenge is an effective challenge. From the values, high investment and future viability (C2), IT security concerns (C5) and lack of government support and legal issues (C6) are the cause challenges, while management commitment (C1), employee fear and resistance (C3) and technical fit and integration of CPS (C4) are effect challenges. The challenge C6 has the highest positive value of 2.51, making it the primary cause challenge, while C1 has the highest negative value of −2.19 making it the most effected challenge. The cause challenges like C2, C5 and C6 indirectly results in the effect challenges or barriers like C1, C3 and C4. The cause challenges are considered the major obstacles to the implementation of Industry 4.0.

5 Conclusion

The paper has presented the key challenges to the adoption of Industry 4.0 in the Indian subcontinent. Six key challenges have identified that influence and can act as barriers to Industry 4.0. For the same, a case industry was selected to analyse the effect of these challenges by using DEMATEL approach.

Management commitment was found out to be the most prominent and influencing challenge for the industry. The guidance and direction of management are utmost important to bring any organizational change. It influences the decisions and actions of all the components in the industrial environment. Integration of CPS can almost equally affect the adoption of Industry 4.0. As CPS requires advanced technologies involving sensors, etc., its utilization is a complicated and difficult task. High monetary investment and lack of commercial analysis of the components of Industry 4.0 also creates a dilemma. The support of the government and its policies is the major challenge that affects other challenges. The Indian government has come up with new initiatives like Make in India, etc., but in order to acquire the benefits of Industry 4.0, it must develop a modelling and framework approach. The government must also develop consultancies in collaboration with top research institutes that can guide the industries. Also, ease of policies like import of foreign technologies, etc., can motivate the industrial management, to take a step forward in the direction of Industry 4.0.

Further, research can be amplified by analysing the above challenges in the context of other industries like machine tool and chemical. Also, a fuzzy-DEMATEL or grey-DEMATEL, a hybrid approach can be utilized to better incorporate the uncertainties that arise during response collection.

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