An Analysis of Causal Relationships Among Challenges Impeding Adoption of Industry 4.0 Through DEMATEL Technique

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Industries must be more innovative than ever before to face rising global competition and stay in the market today. These now aim to enhance operational efficiency by using different advanced technology tools and techniques of Industry 4.0, satisfying the varying customer needs with products of the highest quality offered at minimal costs. With different bottlenecks faced in industrial operations, the large-scale adoption of such systems faces multiple impediments relevant to the country's socio-economic make-up, and therefore, nine pertinent barriers deterring India's transition to Industry 4.0 with varying interdependencies and importance are identified. Data collected from multiple industry experts is subsequently analyzed using the DEMATEL (Decision Making Trial and Evaluation Laboratory) technique to identify the key barriers having the biggest influence over India's industrial landscape based on their cause-effect value and importance scores. The study conclusively ends with discussing the analysis findings for use in solving complex industry problems and identifying new roles, work environments, and skills required in different domains for the adoption of systems of Industry 4.0 in India.

Keywords: *Industry 4.0, Decentralisation, Cyber-Physical Systems, Computer Networks, Barriers, DEMATEL*

1. INTRODUCTION

India has a population of over a billion people, and its market appetite today is greater than ever, attributed to reasons varying from growing international trade to improved local market advertising. Industry 4.0 is themed on the capability of 'mass personalization' [1] through advanced digital means where upcoming initiatives like ‘Digital India’ promise a crucial boost to the striving Indian economy. Manufacturing, an 'Engine of Growth' that has shaped the fortune of several national economies today, is among India's top priorities for development. With initiatives like 'Make in India', the intelligent systems of Industry 4.0 functioning on principles of smart manufacturing can suitably be used to turn India into a global manufacturing hub by promoting skills among different classes of workers, especially those with blue-collar professions. Therefore, the unprecedented focus of Industry 4.0 is expected to integrate the various critical elements of India's economy to create an optimum balance of the ever-sensitive supply-demand equation for subsequent well-being.

Highlighted from its small-scale implementation observed in India to date, multiple barriers relevant to India's economy, politics, demographics, and culture deterring its adoption of Industry 4.0. There is a pressing need today to identify these barriers to subsequently adopt the different systems of Industry 4.0 and reflect upon the merits as well as demerits in quick succession.

The authors reviewed the academic literature to identify nine barriers relevant to the scope of this study. Since economies operate with a precise level of interdependence, the identified barriers have varying interrelationships and hold an individual level of importance that is critical to their existence[2]. Therefore, to determine the overall significance of the barriers, data on their interactions is collected from industry experts from different sectors of the Indian economy. This is identified as a Multi-Criteria Decision-Making (MCDM) problem. Therefore, the DEMATEL (Decision Making Trial and Evaluation Laboratory) technique is used to recognize the quantitative and qualitative aspects of the interrelationship of the barriers using their causal behavior by calculating a "cause-effect value" and numerical order of importance using the "importance score". The "cause-effect value" shows the extent to which each barrier is a cause or effect w.r.t. other barriers in the identified system of the Indian industrial framework, along with the "importance score," which gives an extent of how important each barrier becomes due to its relationship with other barriers.

Therefore, the authors present critical ‘cause’ barriers ranked in order of ‘importance’ as their findings in this study. Entities transitioning to Industry 4.0 in India can prioritize addressing these ‘cause’ barriers due to their significance and influence over other interacting barriers part of the system.

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2. LITERATURE REVIEW

The scope of Industry 4.0 in India and current systems in use, along with the limitations in their adoption, are studied in the literature review.

2.1 Scope of Industry 4.0 in India

Functioning on the greater use of new and sophisticated technologies of Industry 4.0 like additive manufac–turing, robotics, and data analytics, industries are now capable of creating highly efficient personalized pro–ducts [3], shaping a new class of consumers in the ongoing trend of consumerism in India. Therefore, the demand for different products of growing quality is expected to rise multi-fold in the Indian markets, prom–pting a surge in employment and defying the appre–hension of large-scale loss of jobs.

The need for a skilled workforce can be met by reviewing India's demographic dividend, where 60% of the population comprises people below the age of 35 [4]. A significant share of this workforce, with qualifi–cations in STEM (Science, Technology, Engineering & Mathematics) and management disciplines, can easily be granted suitable employment under a systematic training and recruitment program. With several govern–ment organizations and public sector undertakings in fields like aerospace, automotive, petroleum, and agri–culture in operation, government resources can also be used to train this new workforce. Along with benefitting the respective organization, these skills can also prompt individuals to start their enterprises and contribute to the nation's economy by adding to the growing number of Micro, Small, and Medium Enterprises (MSMEs) [5]. These resources can also be availed to different stakeholders in industries and academia to boost various research and development efforts through increased collaborations, promoting Industry 4.0's theme of system integration [6].

Agriculture is one of the largest contributors to the Indian economy and is innately linked to the country's social system and values. The domain of Agricultural Cyber-Physical Systems (ACPS) that uses technologies of IoT, big data analytics, and cloud computing is now on the rise and promises unique functionalities over conventional agricultural decision support systems. Similar yield is also expected to improve precision agriculture methodologies where practices like variable rate application (VRA) can be augmented by operating on varying field inputs on soil and crop properties using WSANs (wireless sensor and actuator networks).

Sectors like railways that manage major client loads in day-to-day functioning can use combinations of different machine learning and big data analytics algo–rithms to evaluate chunks of process data in real time and ease the load on the strained administrative appa–ratus currently in use. For instance, Fantoni et al. [7] discuss an intelligent framework of text mining tools that translate the managerial, technical, and legal details of tenders for finalizing contracts within desired time frames. Tech–nologies like Robotic Process Automation (RPA) can also be used in such operations where organizations can increase profits by reducing human resources costs and bringing down workload by significant margins.

Logistics accounts for around 14% of India's GDP [8], and the need for more utility can put the interests of multiple stakeholders at risk. The physical Internet, a sophisticated apparatus for enhanced logistic operations, offers significant capabilities compared to a traditional logistic network [9] and suits India's needs for efficient long-term supply chain management solutions. Wareho–using is a critical part of such efforts where smart ware–houses using technologies of augmented reality, virtual reality, IoT, and artificial intelligence can also be emp–loyed for real-time operations of material collection, storage, inspection, and distribution [10]. Forecasting results show a need for improved goods handling capa–bility in India's ports to cater to the growing economy [11]. Methods of Industry 4.0 can be adapted to serve this need by simultaneously increasing cost-effecti–veness, boosting competitiveness, and redefining seafa–rers' role [12,13].

Most people in India reside in areas with air quality below recommended levels[14], which is attributed to rapid urbanization, excessive greenhouse gas emissions, and the constant release of untreated industrial wastes. Predictive maintenance algorithms using volumes of real-time and historical data can be employed to assess these rising pollution levels and devise suitable policies to aid the required control efforts.

Waste treatment is a major challenge to civic authorities in India that can be dealt with using sophisticated systems of Industry 4.0. An example includes using the sensor-fusion-based waste sorting setup devised by Agamuthu [15], which is beneficial regarding material yields and secondary metal purities at minimal power requirements.

2.2 Implementation and Observed Limitations

Limited sectors part of the socio-economic framework of India enjoy the benefits of Industry 4.0, a majority of which are undertaken by new ventures and SMEs that usually lack the appropriate knowledge and financial resources to expand to larger sectors of the economy [16].

Many researchers also believe that the systems in use need more capability for long-term adoption due to reasons like shortage of human resources, outdated technical ware, and poor organizational management.

For instance, Shankarnarayanand Ramakrishna [17] uses different artificial intelligence and big data algo–rithms to create a system for soil health management. But this setup is plagued by poor operational procedures where soil samples collected from one place are trans–ported to distant chemistry labs, severely damaging the system and causing probable loss of quality of samples.

Prevalent prototyping technologies like additive manufacturing are also finding limited use where only selective cost-intensive sectors like aerospace can include the production of sophisticated 3D printed parts in their value chains[18].

There is also a need for provisions for the use of such technologies as part of a sustainable form of development with the intent to minimize material waste, improve energy efficiency and increase the service life of components.

3. RESEARCH GAP & PROBLEM DESCRIPTION

It is concluded from the observed limitations of the systems implemented in India that multiple barriers exist, deterring India's transition to Industry 4.0. Under the subsequent literature review, it is inferred that there needs to be a holistic view of the varying critical aspects of India's socioeconomic makeup required to formulate such barriers.

For instance, Kamble et al. [19] discuss a universal framework for adopting Industry 4.0, significantly focu–sing on the Indian landscape but lacking applicability due to not accounting for any barriers that may be faced upon practical implementation.

Miskiewicz and Wolniak[20], Nagy et al.[21] have contributed significantly to learning the pros and cons of the use of systems of Industry 4.0 in an economy but need to precisely account for the real-life barriers that could deter such a transition.

Sony and Naik [22] present an atheoretical frame–work considering the crucial metric of socio-technical implications in the Indian scenario but misses out on accounting for the country-specific aspects that majorly dictate the structure of the barriers. Similarly, Kumar et al. [23] discuss the different challenges to the adoption of systems of Industry 4.0 in India but need more detail in the presented literature.

The authors also found a need for more opinions from working professionals and industry experts in framing the barriers, limiting their scope to the availabilities of the academia or expert individuals only from select regions of the nation. Additionally, findings on the interrelationships of these barriers with such a lack of comprehensive perspective were also found to miss out on the critical aspects of their interdependence.

Therefore, considering the discussed gap in the literature, the objectives of this study are as follows.

- To create a detailed log of barriers deterring India's transition to Industry 4.0 with a holistic view of relevant factors identified by a review of academic literature and consultation with industry experts.
- To account for the respective interrelationships and importance of barriers by processing data collected from industry experts from different sectors of the economy using the DEMATEL technique.

Under the findings of the performed data analysis, the research concludes by identifying the most critical barriers to tackling, which would be crucial for India's transition to Industry 4.0. The framework adopted in this study is presented in Figure 1.

4. METHODOLOGY

The authors performed a vigorous literature review to identify eight categories of barriers from domains relevant to the adoption of Industry 4.0 in India, following which nine barriers deterring India's shift to Industry 4.0 were recognized, as shown in Table 1.

The study required a Multi-Criteria Decision-Making (MCDM) technique considering the interrelationship of the different barriers. Therefore, the Decision Making Trial and Evaluation Laboratory (DEMATEL) technique was suitably employed due to its efficient use of visual structures (digraphs) and matrix calculations to solve complex multi-factor interactions [28] among different factors and depict the level of influence of each by generating the "importance ranking", as well as it's typed by devising their causal interrelationship of being a "cause" or "effect".

Other MCDM techniques, like Analytical Hierarchy Process (AHP), could not be used as these only compare each element's (here, barriers) influence over the desired goal, ignoring the critical interrelationships among them[29]. Structural Equation Modeling (SEM) methods are also used to identify such causal relationships, but they need to fit data to the models better, giving erroneous results [30].

A matrix-form catalog was answered by industry experts from different sectors of the Indian economy, referred to as the resource team[29], where the rating of the extent of influence of each barrier over the other ones, called barrier interaction score [29], was collected. The rating scale ranged from 0 to 4, representing 'no influence', 'less influence', 'medium influence', 'big influence', and 'very big influence', respectively.

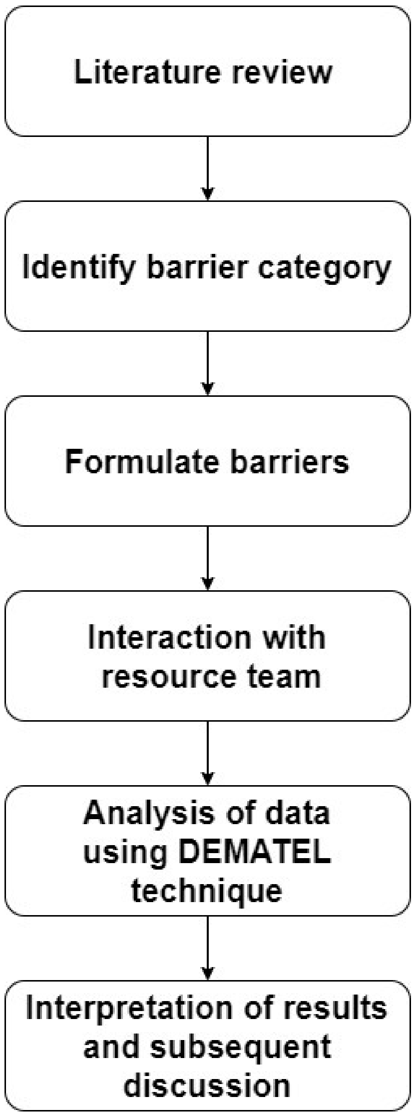

Figure 1. Methodology for identification of key barriers to adoption of Industry 4.0

Table 1. Nine Barriers to Adoption of Industry 4.0

Code	Category	Barrier	Description	Ref.
B1	Human Resource	Lack of skill in blue-collar workers to operate in new work environments.	Due to new concepts like HRC, workers require knowledge of robotic system configuration, programming, etc...	[24]
B2	Organisational	Lack of integration between departments.	Inadequate interaction among different departments creates multiple inconveniences to operations.	[23]
B3	Scholastic	Lack of exposure in academia to work with technologies of Industry 4.0	Academia does not focus on introducing technologies like IoT and robotics in higher education curriculums.	[24]
B4	Process-Related	Lack of product personalization capabilities.	Systems needing product personalization capabilities can cater to a consumer-based economy.	[25]
B5	Process-Related	The abundance of old-existing technological infrastructure to be upgraded.	Most technological infrastructure is from the times of Industry 3.0 or before.	[23]
B6	Research & development	Lack of appropriate reference models or requirement engineering data.	There needs to be more documentation on the past implementation of systems of Industry 4.0 in India.	[24]
B7	Technical	Poor cyber security frameworks.	Highly interconnected systems of Industry 4.0 offer greater scope for far-reaching data breaches.	[26]
B8	Government Regulations & Policy	Lack of detailed laws on penalization in cases of accidents by autonomous machines.	Determining accountability for penalization in accidents caused by autonomous and intelligent machines is difficult.	[27]
B9	Infrastructure & Investment	High costs of innovation and infrastructure to develop starting frameworks.	The training of individuals and installation of relevant ware requires organizations to make hefty expenses.	[23]

Table 2. Data collected from experts from various sectors

No.	Industry	No. of Respondents
1.	Automotive	12
2.	Manufacturing	9
3.	Supply Chain Management	8
4.	Banking & Finance	5
5.	Healthcare	4
6.	Marketing & Management	4
7.	Software Engineering	4
8.	Mechanical Design	2
9.	Consumer Appliances	2

The DEMATEL technique processes these matrix responses to term each barrier a cause or effect by computing its unique cause-effect value. An importance score is also computed by which the barriers were put in numerical order of their importance ranking, accounting for their importance in the tested landscape. This devised importance ranking accounts for the barrier's impact on the whole system and vice versa.

Therefore, The performed study refers to the cause-effect value and importance ranking to define 'cause' barriers (in their order of importance), which are most critical to India's shift to Industry 4.0.

5. DEMATEL TECHNIQUE

A 50-member resource team was created for this study, primarily after referring to current literature on using the DEMATEL method and the sample sizes authors have chosen. The aim was to include experts from varying industries, and therefore, the snowball sampling technique was adopted where individuals from different industries chosen by authors were asked to further connect them with more experts who could contribute to this study. The number of respondents from the different industries is presented in Table 2.

The mathematical model of the DEMATEL techni–que is subsequently created to process the response matrices (9 x 9) to obtain the importance score and cause-effect value.

5.1 Mathematical Model

All the response matrices are collected to devise the direct-relation matrix (X), as shown in Eq. (1)

$$X = \begin{bmatrix} 0 & \cdots & X_{91} \\ \vdots & \ddots & \vdots \\ X_{19} & \cdots & 0 \end{bmatrix} \quad (1)$$

where the element (X_{ij}) is the arithmetic mean of the corresponding elements in the H response matrices (here, H = 50), as shown in Eq. (2)

$$X_{ij} \frac{1}{H} \sum_{p=1}^{H} x^{p}{}_{ij} \tag{2}$$

k, the maximum of the sum of all rows and columns is calculated for the normalization of the direct-relation matrix, as shown in Eq. (3)

$$k = \max\left\{\max \sum_{i=1}^{n} X_{ij}, \sum_{i=1}^{n} X_{ij}\right\} \tag{3}$$

where n is the number of barriers.

Each element of the direct-relation matrix is sub–sequently divided by k to obtain the normalized matrix (N) shown in Eq. (4)

$$N = \frac{1}{k} * X \tag{4}$$

The fuzzy total-relation matrix (T) is then obtained by processing the normalized matrix as shown in Eq. (5)

$$T = N \times (1 - N)^{-1} \tag{5}$$

where the normalized matrix is subtracted from an identity matrix, and the inverse is multiplied by a normalized matrix.

The threshold value (also called the limiting value), α, is calculated to eliminate any partial relations and account for the internal relations of the barriers. The arithmetic mean of all the terms of T is calculated to obtain the threshold value, as shown in Eq. (6)

$$\alpha = \frac{1}{n^2} \sum_{i=1}^{n} \quad \sum_{i=1}^{n} T_{ij} \tag{6}$$

All the elements less than the threshold value in the total-relation matrix are reduced to 0, and a revised total-relation matrix (T*) is obtained.

The respective sums of each row (D_i) and each column (R_i) in the total-relation matrix are computed as shown in Eq. (7) and Eq. (8), respectively.

$$D = \sum_{j=1}^{n} T_{ij} \tag{7}$$

$$R = \sum_{i=1}^{n} T_{ij} \tag{8}$$

Table 3. Barrier interaction scores from an industry expert

	B1	B2	B3	B4	B5	B6	B7	B8	B9
B1	0	3	2	2	3	4	3	2	4
B2	4	0	2	3	3	2	1	1	2
B3	3	3	0	4	3	2	2	2	3
B4	3	1	3	0	1	3	1	2	2
B5	3	2	3	1	0	3	2	1	3
B6	4	1	3	2	2	0	2	2	3
B7	3	1	2	1	2	2	0	1	2
B8	3	1	1	1	1	2	1	0	2
B9	2	1	4	2	2	2	1	2	0

Table 4. Direct-relation matrix (X)

	B1	B2	B3	B4	B5	B6	B7	B8	B9
B1	0	2.16	2.5	2.05	2.55	2.61	1.5	2.05	1.72
B2	2.27	0	2.33	2.11	2	2.05	1.67	1.33	2.05
B3	2.67	2.22	0	2.33	2.16	2.27	1.88	1.94	2.22
B4	2.11	1.67	2.77	0	2.38	2.5	1.66	1.5	2.16
B5	2.67	2.05	2.27	2.16	0	2.44	1.88	1.67	2.55
B6	2.38	2.05	2.55	2.61	2.55	0	1.77	1.88	2.67
B7	1.94	1.83	2.11	1.72	1.77	2.05	0	1.61	2
B8	2.16	1.61	2.11	1.38	1.77	1.77	1.67	0	1.77
B9	1.61	1.61	2.67	2.16	2.22	2.11	1.67	1.67	0

Table 5. Normalized direct-relation matrix (N)

	B1	B2	B3	B4	B5	B6	B7	B8	B9
B1	0	0.117	0.135	0.111	0.138	0.141	0.081	0.111	0.093
B2	0.123	0	0.126	0.114	0.108	0.111	0.09	0.072	0.111
B3	0.144	0.12	0	0.126	0.117	0.123	0.102	0.105	0.12
B4	0.114	0.09	0.15	0	0.129	0.135	0.09	0.081	0.117
B5	0.144	0.111	0.123	0.117	0	0.132	0.102	0.09	0.138
B6	0.129	0.111	0.138	0.141	0.138	0	0.096	0.102	0.144
B7	0.105	0.099	0.114	0.093	0.096	0.111	0	0.087	0.108
B8	0.117	0.087	0.114	0.075	0.096	0.096	0.09	0	0.096
B9	0.087	0.087	0.144	0.117	0.12	0.114	0.09	0.09	0

Table 6. Total-relation matrix considering threshold value (T*)

	B1	B2	B3	B4	B5	B6	B7	B8	B9
B1	1.002	0	1.194	1.043	1.107	1.126	0	0	1.054
B2	1.04	0	1.111	0	1.013	1.032	0	0	0.999
B3	1.151	0.997	1.101	1.077	1.114	1.136	0	0	1.098
B4	1.086	0	1.187	0	1.083	1.104	0	0	1.056
B5	1.154	0.992	1.213	1.073	1.012	1.146	0	0	1.115
B6	1.182	1.026	1.268	1.13	1.172	1.069	0	0	1.159
B7	0	0	1.052	0	0	0	0	0	0
B8	0	0	1.006	0	0	0	0	0	0
B9	1.005	0	1.118	0	1.016	1.028	0	0	0

Table 7. Importance score and cause-effect value

Code	D_i	R_i	D_i+R_i	D_i-R_i	Importance Ranking	Cause/ Effect
B1	9.547	9.251	18.798	- 0.296	4	Effect
B2	8.289	8.596	16.884	0.307	7	Cause
B3	10.25	9.475	19.725	- 0.775	1	Effect
B4	8.987	9.086	18.073	0.1	5	Cause
B5	9.391	9.496	18.886	0.105	3	Cause
B6	9.558	9.864	19.422	0.305	2	Cause
B7	7.504	8.175	15.679	0.67	8	Cause
B8	7.51	7.784	15.294	0.275	9	Cause
B9	9.229	8.528	17.767	- 0.691	6	Effect

The importance score (D_i+R_i) and cause-effect value (D_i-R_i) are, therefore, obtained using the value of D_i and R_i. A greater importance score signifies higher importance in the entire system and vice-versa. Whereas a negative cause-effect value represents an effective barrier, and a positive value denotes a cause barrier.

5.2 Analysis

A response matrix filled by an expert from the manufacturing sector is shown in Table 3.

The direct-relation matrix (X) derived is shown in Table 4. The normalized direct-relation matrix (N) computed subsequently is presented in Table 5. Considering the fuzzy behavior of the normalized matrix, the total-relation matrix (T) is then obtained. The threshold value (α) is calculated to be 0.991, and the total-relation matrix is modified to obtain T* where all the elements less than α are reduced to 0, shown in Table 6.

The sums of rows (D_i) and sums of columns (R_i), along with the importance score (D_i+R_i), cause-effect value (D_i-R_i), importance ranking, and cause-effect behavior, are obtained and shown in Table 7.

6. RESULTS & DISCUSSIONS

The respective importance ranking and cause-effect value are therefore referred to from the analysis to discuss the key barriers deterring India's transition to Industry 4.0.

6.1 Results

As per the importance ranking, 'Lack of exposure in academia to work with technologies of Industry 4.0' (B3) has the highest importance in the discussed system. The following order is 'Lack of appropriate reference models or requirement engineering data' (B6), 'Abundance of old-existing technological infrastructure to be upgraded' (B5), 'Lack of skill in blue-collar workers to operate in new work environments' (B1), 'Lack of product personalization capabilities' (B4), 'High costs of innovation and infrastructure to develop starting frameworks' (B9), 'Lack of integration between departments' (B2), 'Poor cyber security frameworks' (B7) and 'Lack of detailed laws on penalization in cases of accidents by autonomous machines' (B8).

The cause-effect diagram using the cause-effect value (D_i-R_i) and importance score (D_i+R_i) is presented in Figure 2.

The magnitude of the net cause-effect value determines the extent of being a cause or effect in the system.

With positive net cause-effect values, 'Poor cyber security frameworks' (B7), 'Lack of integration between departments' (B2), 'Lack of appropriate reference models or requirement engineering data' (B6), 'Lack of detailed laws on penalization in cases of accidents by autonomous machines' (B8), 'Abundance of old-existing technological infrastructure to be upgraded' (B5) and 'Lack of product personalization capabilities' (B4) are the cause barriers in the decreasing order of extent of being a cause.

Similarly, 'Lack of exposure in academia to work with technologies of Industry 4.0' (B3), 'High Costs of R&D to develop starting frameworks' (B9), and 'Lack of skill in blue-collar workers to operate in new work environments' (B1) are the effect barriers in the decreasing order of extent of being an effect.

Referring to the modified total-relation matrix (T*), the cause-effect values, and importance scores, the causal relationship digraph is prepared to depict the nature of the influence of all barriers over others and their own selves, shown in Figure 3. The considered relationship comprises being 'influenced over', 'influenced by itself', and 'mutually influenced'.

6.2 Discussions

'Lack of detailed laws on penalization in cases of accidents by autonomous machines' (B8) has the least importance in the system, carrying a single interaction depicted in the causal relationship digraph. Similarly, 'Lack of exposure in academia to work with techno–logies of Industry 4.0' (B3) has the highest importance, carrying the most relationships/interactions in the digraph. Since this barrier also has a negative cause-effect value (D_i-R_i), it is simultaneously an effective barrier that can be influenced by other barriers active in the system[29] and, therefore, cannot be considered a critical barrier.

The authors review the cause-barriers (in decre–asing order of importance score) as the critical barriers deterring India's transition to Industry 4.0. 'Lack of appropriate reference models or requirement enginee–ring data' (B6) is, therefore, termed the most critical barrier due to being the cause barrier with the highest importance ranking. Requirement Engineering (RE) comprises a set of procedures that include communi–cating product function, understanding its value, and managing cross-cutting concerns[31]. Along with a lack of literature for devising such a framework concerning the use of systems of Industry 4.0 in India, the existing industrial setting using various legacy and conventional systems also lack such comprehensive documenting procedures[32], and significant efforts are; therefore, required to account for this scarce background.

'Abundance of old-existing technological infrastruc–ture to be upgraded' (B5) is a critical cause-barrier, particularly in the Indian context [4]. Retrofitting exis–ting machinery is deemed useful for cost-cutting [33], but organizations need to avoid it due to the scale of financial investment and technical complexities the process brings with itself [34]. Data is at the center of Industry 4.0, but its core dataflow pipelines need a major upgrade of the existing architecture for at-par performance, scalability, and availability standards [35].

'Lack of product personalization capabilities' (B4) is a critical cause-barrier that defies the core principle of advanced product personalization capabilities in Indus–try 4.0. This conceived capability has strongly been considered to make suitable use of marketing and technical strategies to stabilize the supply-demand inte–raction, parallelly minimizing effects of over-consump–tion[36] like depletion of resources and impoverishment of biodiversity. A lack of such a capability can cause major damage to the country's growth and development attributes and is a matter of concern for the Indian industrial faction.

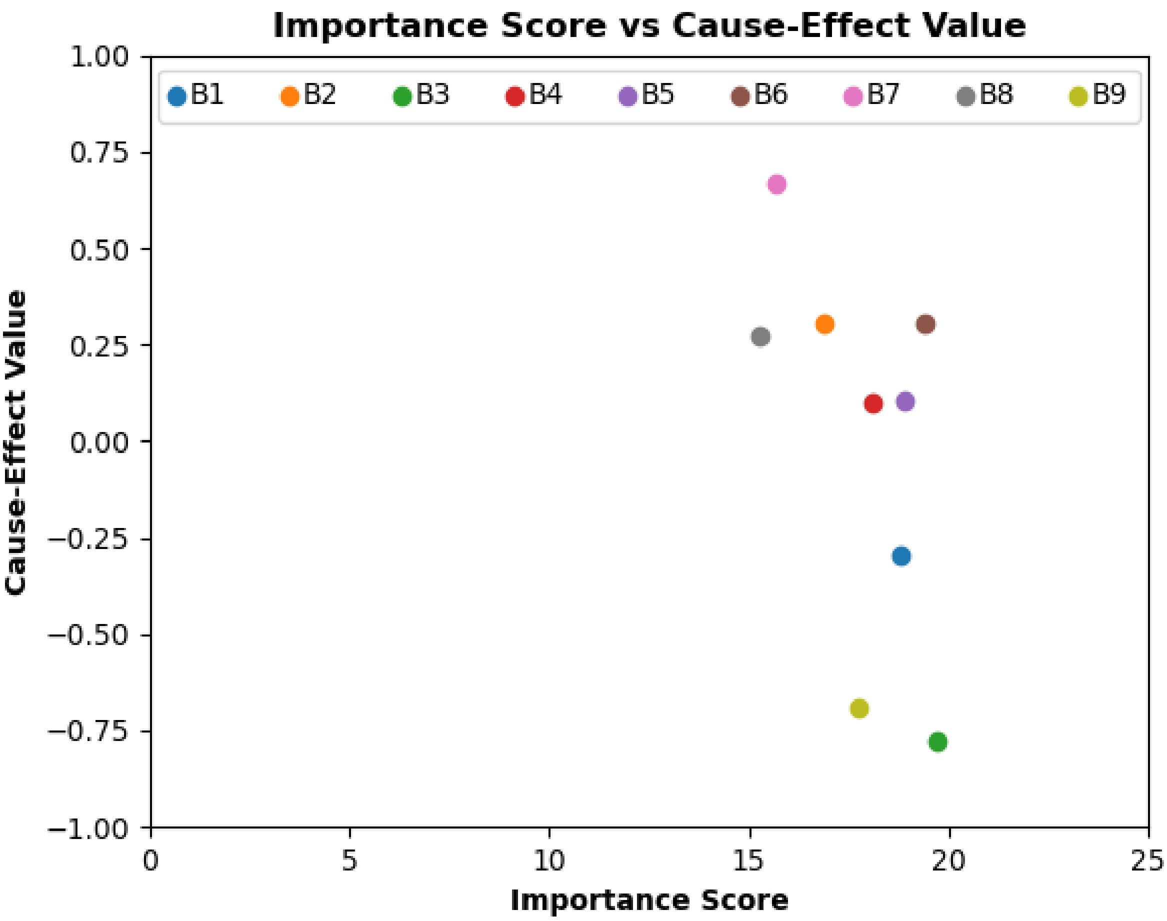

Figure 2. Importance Score vs. Cause-Effect Value of Barriers to the Adoption of Industry 4.0

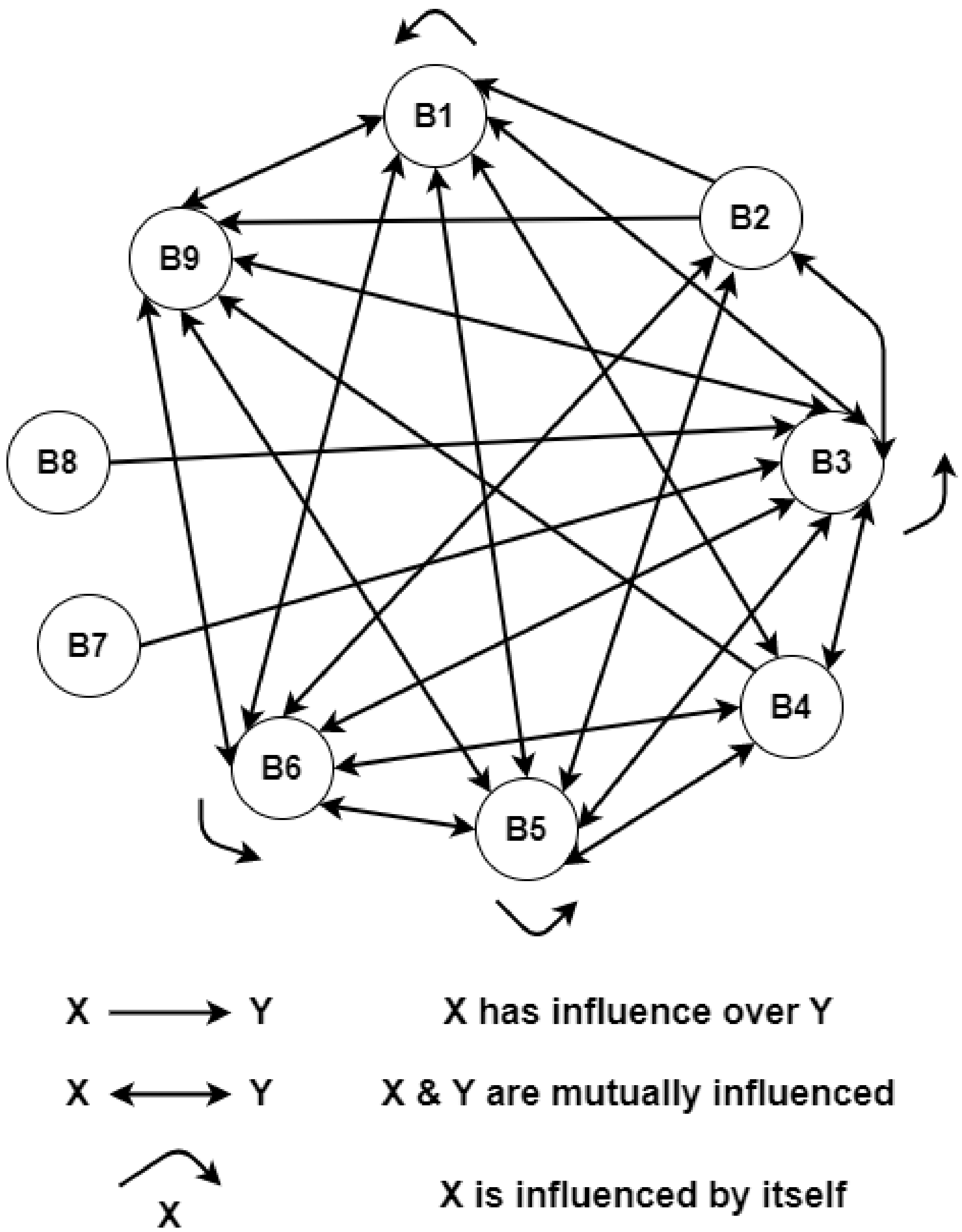

Figure 3. Digraph for the interrelationship of barriers to the adoption of Industry 4.0

With individuals from various walks of technology, management, legal services, and finances required to work in synergy in Industry 4.0, 'Lack of integration between departments' (B2) is a critical cause-barrier concerned with Industry 4.0's system integration element. Any influence over the personal and professional relationships of individuals can severely affect the organization's functioning. Likewise, the Product Service Scheme (PSS) is a critical aspect of Industry 4.0 that functions on a fine relation between the tangible (product) and intangible (service) assets in the end output offered to the customer[37] and therefore, relies on a robust relationship among different departments to meet the proposed objective.

'Poor cyber security frameworks' (B7) is suitably termed a critical barrier considering the growing use of interconnected systems functioning on advanced Information and Communication Technologies (ICT). The majority of industry-level operations in Industry 4.0 are performed through varying digital means [38], where the constant H2M (Human to Machine) and M2M (Machine to Machine) interactions can put critical personal and organizational data at risk if the required measures are not in place. With the rising use of ubiquitous systems carrying positioning capabilities like GPS, such breaches now affect our daily life, as seen in the ongoing effort of certain service providers, cellphone companies, and developers of smartphone applications to collect the mobility traces of several individuals and violating their privacy as part of their research and development scheme[39]. People today are, therefore, reluctant to upgrade their equipment, fearing major losses through such instances of data breaches. A lack of exposure to the capability of malicious ware active on the global Internet [26] is a major reason that organizations in India are particularly required to put a special emphasis on building a strong and robust cyber security network today.

'Lack of detailed laws on penalization in cases of accidents by autonomous machines' (B8) is a cause-barrier deterring India's shift to Industry 4.0, considering the aspect of government regulations and policies. Marda [27] says that governments and policymakers need an outlook on technologies like AI and, therefore, need to address their different ethical, social, and technical implications, which are later reflected in their policy decisions. Several real-time operations are performed today in different cyber and physical spaces in environments that lack the required cyber security frameworks. Therefore, it is urgently required to frame necessary laws for accountability and punishment in times of mishappenings like data breaches and on-site accidents involving the installed intelligent ware like robots.

7. CONCLUSION

The scope, current use, and limitations of systems of Industry 4.0 in India have been discussed in detail in the paper. A study of the barriers deterring India's transition to Industry 4.0 has been performed. All the barriers have a certain level of interdependence, and therefore, the DEMATEL technique has been used accordingly to devise their cause-effect behavior and importance in the system. Analyzing data collected from 50 industry experts, the research concludes by identifying the 'Lack of appropriate reference models or requirement engineering data' as a primary barrier to India's transition to the adoption of systems of Industry 4.0 being the cause barrier, with the highest importance. This research can be used to modify many existing processes in industries, including business process re-engineering (BPR) for increased growth at reduced expense. Creating a holistic view of the Indian economy in studying the respective barriers, this study paves the way for dedicated research on selective sectors most critical to India's transition to Industry 4.0. Interested parties can also refer to this literature to devise a framework for the full-scale adoption of Industry 4.0 in India.

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АНАЛИЗА УЗРОЧНО-ПОСЛЕДИЧНИХ ВЕЗА МЕЂУ ИЗАЗОВИМА КОЈИ ОМЕТАЈУ УСВАЈАЊЕ ИНДУСТРИЈЕ 4.0 КРОЗ ДЕМАТЕЛ ТЕХНИКУ

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Индустрије морају бити иновативније него икада раније да би се суочиле са растућом глобалном конкуренцијом и данас на тржишту. Они сада имају за циљ да побољшају оперативну ефикасност коришћењем различитих напредних технолошких алата и техника Индустрије 4.0, задовољавајући различите потребе купаца са производима највишег квалитета који се нуде уз минималне трошкове. Уз различита уска грла са којима се суочавају у индустријским операцијама, широко усвајање таквих система суочава се са вишеструким препрекама релевантним за друштвено-економски састав земље, па је стога идентификовано девет релевантних баријера које спречавају транзицију Индије ка Индустрији 4.0 са различитим међузависностима и значајем. Подаци прикупљени од више експерата из индустрије се накнадно ана–лизирају коришћењем ДЕМАТЕЛ (Лабораторија за

доношење одлука за испитивање и евалуацију) технике како би се идентификовале кључне препреке које имају највећи утицај на индијски индустријски пејзаж на основу њихове узрочно-последичне вредности и оцене важности. Студија се коначно завршава расправом о налазима анализе за употребу у решавању сложених индустријских проблема и идентификацији нових улога, радних окружења и вештина потребних у различитим доменима за усвајање система Индустрије 4.0 у Индији.