Proceedings of the 2nd Indian International Conference on Industrial Engineering and Operations Management
Warangal, Telangana, India, August 16-18, 2022

Analysis of Barriers to the Implementation of Industry 4.0 in SMEs of India Using A.H.P, Fuzzy-ISM & MICMAC Approach

K. Pavan
M.Tech, Department of Industrial Engineering
National Institute of Technology (NIT), Jalandhar, India
Pavankotni97@gmail.com

Anish Sachdeva
Professor, Department of Industrial Engineering
National Institute of Technology (NIT), Jalandhar, India
asachdeva@nitj.ac.in

Vinay Sharma
Ph.D., Department of Industrial Engineering
National Institute of Technology (NIT), Jalandhar, India
Sharma.vinay1992@gmail.com

Abstract

In the present scenario, industries are trying to increase their productivity and it is easily acquired with the execution of Industry4.0 (I4.0) technologies in industries. Not only the productivity but also the smooth flow of supply chain in industries etc. Even though there are several fruitful advantages, there is still a lack in the execution of I4.0 mainly in small and medium-sized industries of different sectors. Certain hindrances are the root cause of this dearth in industries. A few papers trying to figure out the same issue but it has been found some of the barriers are missing in their analysis and the ranking of barriers is not focused on. Consequently, the primary theme of the research is to find the barriers by reviewing several research papers and ranking them by collecting data with the help of different experts through questionnaires for pair-wise comparison matrix, working in SMEs. The Analytical Hierarchy Process technique has been used to rank the barriers and find the relative importance. In this study, it has been found that 21 barriers are responsible for creating hindrances to the execution of I4.0 technologies in SMEs. Out of the 21 barriers, 12 important barriers are selected for further analysis. After choosing the twelve barriers, it is necessary to explore their interactions and identify the ones that have the most influence over the others. This is achieved by the Fuzzy-Interpretive Structural Modelling Approach and MICMAC analysis of Industry 4.0.

Keywords
SMEs, Industry 4.0, MCDM, F-ISM, AHP, and MICMAC.

1. Introduction
Small and medium-size enterprises (SMEs) are having unique definitions as per countries. (Venkatesh and Muthiah 2012) explained about SMEs that due to their major contribution to output, exports, and employment, small and medium-sized industries are plays a major role in the economic rate of Indian countries. The small sector is a significant source of employment for millions of people are available and the laborers are available for cheap in India and resources are expensive. (Dutta et al. 2020) pointed out that the growth of the Indian economy also depends mostly on the manufacturing sector, Indian government has created a policy in 2011, known as the *National manufacturing* policy to induce the advantages of I4.0 in industries.

Singh et al. (2008), explained in his study about the definition of SMEs, according to different countries like USA considering industries has “very small” if employees are less than 20, “small” if the employees are in between 22-99, “medium” if the employees are in between 100 to 499, Vietnam generally not have any fixed definition but normally

© IEOM Society International

considered SME as less than 200 employees, Thailand, Canada, Germany and mostly many countries are explaining SME in terms of *employees*, But according to India "tiny" is considered as less than 2.5 million rupee of investment in plant, "small" is explained as less than 10 million rupees of investment in plant, "medium" is considered as less than 100 million of rupees of investment in plant. So, generally, SMEs are explained as per employees and as investments explained in different countries.

Rathod et al. (2016) stated that Small and medium-sized industries (SMEs) have had outstanding growth, which was anticipated and carried out in the economic progress of the nation since 1947. It has aided in the expansion of the GDP by exporting and creating jobs. The SME industry has made an exceptional contribution to the nation's socio-economic progress. The fact SMEs account for more than 95% of the industrial units, 40% of the industrial production, and 36% of the total as a percentage of all exports. More than 18 million people work for various SME businesses.

According to the annual report 2021 of micro, small and medium industries from the Indian government has analyzed that in the 2018 financial year the share of MSMEs is 30.27% of the total GDP (Growth Domestic Product) of India. So, according to this, it has been declared that SMEs play a significant part in the economic growth of India. So for the development of SMEs, there is a need to execute I4.0 technologies in industries for industrial growth in which it is transform the way companies manufacture, manage and their product distribution but *due to some of the barriers the execution of Industry4.0 is not sufficient enough for the industrial growth.*

Recently Nokia Company had a five years contract with Wipro for the digital transformation of company this tells that implementation of Industry 4.0 technologies are essential and also challenging!!

1.1 Objectives
The main objective of this study is to identify those hindrances called as barriers for implementation of technologies, analysing the most important barrier among them, and identifying the interrelationship among them.

2. Literature Review
2.1 Industry 4.0 (I4.0)
Lasi et al (2014), in the background of Industry 4.0, James watt developed the steam engine and the place of revolution in mechanical types of equipment are evolved. There are mainly four types of industrial revolutions that are done now. The first type of industrial revolution is based on weaving, mechanization, and steam energy. The second type of industrial revolution is mainly on the types of mass production, assembly line, and electrical energy. The next type of evolution in industries is rooted to automation, computers in which all the work is done through automation and labor are decreased. Implementation of IT technologies is increased. The latest type of revolution in industries is established on cyber-physical systems and networks. Smart factories mainly follow five factors connected, optimized, transparent, proactive, and agile play a major role in improving the production process.

Dilberoglu et al. (2017) discussed that additive manufacturing is the process of forming a 3-d object by deposition of material as layers one over the other till the finished product is made and the finished product is initially designed with the help of software such as CAD, etc. Haleem et al. (2020) have described that additive manufacturing has an impact on supply chain management in the industries as in the traditional supply chain there are a lot of drawbacks such as lead times of getting accessories from other companies into industries, the transportation cost is high and these all are being solved with the help of additive manufacturing as the goods are formed in the industries itself and decreases the transportation cost, Ultimately helps in transferring from the traditional supply chain of SMEs into digital technology, have a significant impact on an industries' productivity (Figure 1).

© IEOM Society International

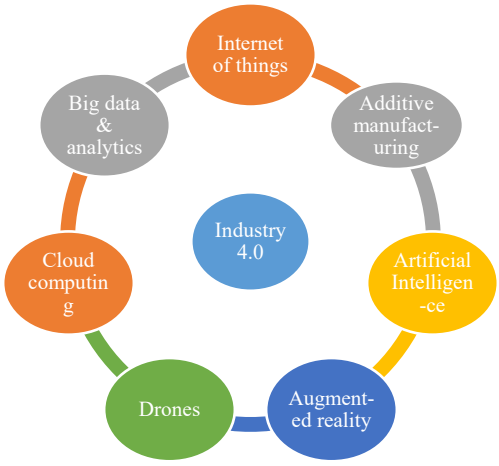

Figure 1. Technologies in I4.0

Kumar and Kalse (2021) discussed that artificial intelligence is the technique of simulating human intelligence into machines. The goal; of artificial intelligence is to have the capability to learn, analyze and predict. Because of its tremendous use, most big companies have already implemented Artificial intelligence for their growth such as google, amazon, Facebook, etc.

Rauschnabel et al (2018) make to understand the difference between virtual reality and augmented reality, augmented reality is adding a certain layer of the digital environment in combination with the real world. On the other hand, virtual reality is creating a digital environment around the surroundings. Augmented reality is in the form of glasses, contact lenses, and handheld, eye taps that are used for the workers to follow the instructions while working. Some type of augmented reality equipment is used to observe the 3D models and helps to see the interior parts, augmented reality is used for tracking.

Abiodun (2020) explains that drone is a flying robot that can be controlled with a remote system or with the automation that is inserted in the drone itself with software-controlled plans (*Less danger for the employee in the work field)*. (Said et al. 2021) stated that Drones made of automation are having the ability to fulfill the requirements in several applications. These can be useful in the mining sector for inspecting the infrastructure, security reasons, observing the works, and urgent situation. (Bamburry 2015) explained that Drones are also used by food delivery organizations to deliver products in less time. (Ercan 2010) demonstrated Cloud computing is achieving organizational goals with the use of cloud technology, it includes servers, data centers, software, and analytics over the internet to provide flexible resources, and economically beneficial

Vemula et al. (2022) have explained the whole world is enhanced with new technologies and that people are familiar with digital cash transactions, stock trading, insurance, and digital bills these all tend to increase the amount of data. Tiwari et al (2018), stated that big data is the technology that collects the right data and utilizes this data to solve the different issues that occur in the industries of different types of sectors such as manufacturing, education, and health services. Intelligent sensors can be easily optimized according to customer requirements by using this data. This technology is a valuable source to predict the failure in the process and mitigate the risk in operational management based on market statistics (Javaid et al. 2021). (Hermon and Williams 2014) has discussed real-life practices *Healthcare* is continuously growing in digital technologies by using this big data they can make custom-made medicines, decrease fault practices, and increase the effectiveness of treatments

Bach et al. (2019) pointed that out in the financial sector, Banks are having the information of every transaction made by individuals and the salary deposit in their account based on that they can provide the ability to screen loans can provide to the individuals. (Baig et al. 2021) have explained in the education sector, a lot of data is stored in the form of videos as the people or students are interested in video-based training that it makes progressively intuitive. Even telecom companies can be able to get a profit from utilizing the customer's data by sending advertisements according to their interest, etc.

© IEOM Society International

In the recent days, some of the studies have been published to explain the barriers that are impacting the execution of I4.0 in several industries of different sectors such as. (Kumar et al. 2022) described certain obstacles to I4.0 adoption in the food supply chain as in the aspect the economy and the barriers *are not being aware of technologies to stake-holders, risk in cyber resources, participation of industries are poor, lack of infrastructure on basis of technology and skilled workers are not sufficient enough*, and the analysis is done by the DEMATEL approach and the *high investment, lack of awareness and insufficient technological infrastructure* are considered as significant barriers for adoption of I4.0. Similarly barriers are collected from literature review is explained in detail below.

The obstacles that interfere with our workflow or procedure are known as barriers. This study has explored the challenges encountered while implementing Industry 4.0 technologies in the sectors that exist to serve the small and medium-sized businesses that were previously covered. After conducting a thorough analysis of the literature, which included information on the obstacles and difficulties the SME sector faces, 21 obstacles were gathered and classified into the four primary categories. 21 barriers were collected under the categories of 4 global variables through the Bibliography study and experts' opinions (Table 1).

Table 1. Previous literature on analysis of barriers for I4.0

Types of industries and areas	Analysis	References
Cloth industry, Manufacturing organizations, area on integration lean with I4.0, and execution of digital transformation in supply chain	ISM & MICMAC	Majumdar et al. (2021), Vigneshvaran et al. (2020), Prakash Agrawal (2020), Kumar et al. (2021)
Food supply chain and SMEs	DEMATEL	Kumar et al. (2020)
Investigation on emerging economy	SEM	Chetna et al. (2020)
Construction industry	Descriptive statistics	Davikkumar et al. (2020)
Small, and medium size manufacturers	Regression & correlation	Jan Stentoft et al. (2019)
Analysing barriers to I4.0	Best-Worst	Suhaib et al. (2020)
Agricultural supply chain, and selection of third-party logistics	ISM-ANP	Kumar et al. (2021), Thakkar et al. (2005)
Manufacturing sector of Indian industries	AHP-ANP	Nimawat and Gidwani (2021)
Green supply chain management, Pharmaceutical industries	ISM & Fuzzy-MICMAC	Dube and Gawande (2016), Jamwal et al. (2020)
Obstacles in context of smart-cities regarding Big data	ISM, Fuzzy-MICMAC & DEMATEL	Khan et al. (2021)

2.2 Barriers to Effective Execution of I4.0 in SMEs

The identification of barriers for any methodology deals with the study of through literature which is a tedious task and involve multi perceptive study of the subject under study. In this study the focus is on the identification of the various challenges which hampers the implication of I4.0 in the SME sectors. The challenges thus identified through literature has been divided into four major categories. The key challenges are discussed below

Strategic Barriers:

Unclear economic benefits of Industry4.0, There is no clear vision or idea over investments and long-term returns by implementing digitalization in industries (Nguyen et al. 2019, Chauhan et al. 2020).

Lack of Research & development in digital SCM, this barrier states that in the present scenario, many Industries are having trouble using digital technology during their business development as they do not have enough research to identify the importance of I4.0 technologies in SMEs (Nguyen et al. 2019).

Lack of Government support and policies, apart from other barriers, the government should play an important role with their support by the subsidies, policies effects in implementation of digitalization in SMEs (Davikkumar et al. 2020, Nguyen et al. 2019).

Lack of investments, SMEs are financially strapped, insufficient availability of the technical resources, and difficult to upgrade and adopt digital technologies (Kumar et al. 2020, Majumdar et al. 2021, Kumar et al. 2021)

Operational costs, After the execution of I4.0 in managing the supply chain of SMEs running cost of the technology daily also acts as a barrier to implementation (Avirag et al. 2021).

Organisational Barriers:

© IEOM Society International

Lack of organizational digital vision strategy, most of the organization's failures when transforming the visionary ideas into digital transformation (Davikkumar et al. 2020, Agrawal. 2020, Chauhan et al. 2020).

Lack of urgency, this barrier is most commonly observed in industries like in organizations having a "status quo" attitude, there is no need for change is required in their organization, the requirements are fulfilled with present approaches (Agrawal 2020).

Continuous education of the employee**,** organizations are familiar that they know technology is updated and the adoption of technology changes. So the employee should be able to learn and adaptable to technology also act as an obstacles to the execution of digitalization in SMEs (Türkes et al. 2020, Stentoft et al. 2019).

Lack of skilled workers**,** the organization is backward in getting skilled workers at working in the field of digitalization in SCM (Florian et al. 2017).

Lack of management, organizations have an essential need to maintain a common mind-set and attitude towards their digital transformation in SMEs of all sectors in the company (Chauhan et al. 2020, Florian et al. 2017).

Employee resistance to change in the execution of I4.0 in SMEs, Integration of SMEs with new technologies may cause fear of job loss to the employee so there may have a chance of resist in change (Vigneshvaran et al. 2020, Kumar et al. 2021).

Miss-aligned business objectives, as many organization is habitual to traditional objectives that are mainly focused on reducing cost and time but in the present era digitalization is concerned with flexibility, speed, real-time inventory, global connectivity, and innovation.so, perspectives of objectives are different may affect as a barrier to the implementation of digitalization (Agrawal 2020).

Lack of top management support, the outcomes with the help of the digital supply chain are huge but still, organizations are not tasting those benefits because of a lack of backing in upper management. Without backing of upper management, workers will oppose change, especially experienced employees, those are not have an idea about the latest technology and its advantages and do not want to perceive them (Agrawal 2020, Vigneshvaran R et al. 2020).

Lack of training and trained staff, to compete with other companies and survive in the market, organizations should assist with the technologies. If the staff is not able to handle the implemented technology then there is no use. Therefore inadequately trained staff is a complex issue for SMEs (Avirag et al. 2021, Daivikkumar et al. 2020)

Technological Barriers:

Lack of Information and communication technology infrastructure and internet-based network, inadequate internet-based networks and not having better ICT infrastructure also affect the Industry SMEs (Nguyen et al. 2019, Daivikkumar, et al. 2020).

Cyber resources, endorsement of technology is dependent on SMEs cyber resources because numerous SMEs share the same supply chain resources (Kumar et al. 2022, Nguyen et al. 2019)

Ineffective Data management, customers are afraid of security issues and the safety of private information. Example: Companies want to develop service-Led strategies to offer services, for that provider needs certain insights from customers but customers are refused to provide their information for developing such insights (Kumar et al. 2021, Peillon et al. 2019).

Incompetent in the swiftness of digital effectiveness, customers are familiar with customized products and services. Therefore organization's technologies and operations may not be sufficient to compete with digital dynamism. Due to this up-gradation is required and employee should adaptable (Kohnke et al 2012, Agrawal et al 2020).

Ethical Barriers:

Cyber security risk, meshing with different technologies such as artificial intelligence, machine learning, cloud hosting, and data analytics causes a cyber security risk (Nguyen et al. 2019).

© IEOM Society International

Legal or regulatory issues, modern cyber-physical network is characterized by the presence of many sensors and machines that interact with each other. This network can create various legal issues due to its complexity (Vigneshvaran et al. 2020, Nguyen et al. 2019).

Risk aversion, fear of failure in adopting new technologies at the organizations or companies (Nguyen et al. 2019)

2.3 Literature gap

Analysis of obstacles to execution of I4.0 is not done broadly like barriers are collected for single industries and a lot of important barriers are missed in the papers that influence as hindrances to implementation.
The previous works that are shown in literature are done to identify the hindrances to the implementation of I4.0 are not sufficient enough to drive the conclusions. But identifying the hindrances is necessary for the execution of I4.0 to modify the industries from traditional to technological industries. Industries are also developed by mitigating the risk caused by hindrances or barriers. So, there is a great need of identifying the essential barriers, and the interrelationship among the barriers and should take action on them for industrial growth.

Following are the key gaps that have been found through the literature review:
As different barriers are explored from different areas of study, in the study it has been observed that for doing ISM analysis or any analysis they considered a minimum 10 to 12 barriers which are just explored by brainstorming. So, by doing this there may have a chance of missing the important barriers.

Even though ISM-MICMAC analysis is to identify the influence of one barrier over the other but in pair-wise comparison, this analysis only tells whether both the barriers are influencing each other, whether one barrier influence other barrier or not, and whether both the barriers are not influencing each other. But it will not focus on the in-between relationships of barriers such as whether one barrier is highly influenced, low influence, and very low influence to another barrier. This research contributes to filling the gaps by answering following questions.

RQ1: Identify the barriers from the Literature review, Rank the barriers using the A.H.P approach from the responses obtained from SMEs
RQ2: Consider 12 important barriers that are obtained from results of A.H.P and with the help of Fuzzy-ISM approach, the hierarchical relationships between barriers are exposed.
RQ3: Evaluation of dependence and driving power is done using Fuzzy-MICMAC analysis.

3. Research Methodology

3.1 Analytical Hierarchy Process

Step-1:
Prepare the questionnaire to get the responses from experts from different SMEs (Table 2).
Step-2:

Table 2. Prepare the pair-wise comparison matrix

	Barrier 1	Barrier 2	Barrier 3
Barrier 1	$r_{1,1}$	$r_{1,2}$	$r_{1,3}$
Barrier 2	$r_{2,1}$	$r_{2,2}$	$r_{2,3}$
Barrier 3	$r_{3,1}$	$r_{3,2}$	$r_{3,3}$

Step-3:
All the matrices values should be normalized, the normalization of one value as shown below for the previous pair-wise comparison matrix example
Let the Normalized value of Barrier 1, 1 is, $x_{1,1} = \frac{r_{1,1}}{r_{1,1}+r_{2,1}+r_{3,1}}$ similarly normalized values are found for all matrix rows and columns
Step-4:
Let the weightage of barrier 1 is $y_1 = \frac{x_{1,1}+x_{1,2}+x_{1,3}}{3}$, again found for all barriers in the study
Step-5:

© IEOM Society International

$\lambda_{max} = \frac{\lambda_1+\lambda_2+\lambda_3}{3}$, Where $\lambda_1 = \frac{y_1 * g_{1,1} + y_2 * g_{1,2} + y_3 * g_{1,3}}{y_1}$, similarly λ_2, λ_3 are found for the example shown above

Calculate consistency ratio, is the ratio of consistency concerning to random index using the formula, where consistency Index C.I=$\frac{\lambda_{max}-n}{n-1}$, n: Matrix size and standard random index table is used.

If the consistency ratio is less than 0.1 is considered to be consistent, if it is greater than 0.1 then values in the pair-wise comparison matrix must be reviewed. (Harputlugil 2018).

3.2 FUZZY-Interpretive Structural Modelling Approach

To go through the approach, it has been needed to understand the Fuzzy numbers, types of Fuzzy numbers and their properties.

FUZZY-numbers:

Ardil (2021), demonstrated Fuzzy-numbers as a special Fuzzy set of$T = \{l, \mu_T(l), l \in R\}$, where *l* has a value in the real line, R: $\{-\infty \leq l \leq \infty\}$ and $\mu_T(l)$ is a membership function in the interval [0, 1], Fuzzy numbers can be classified into variety of categories such as triangular, trapezoidal and Gaussian. In this study it has been used triangular Fuzzy-numbers.

Triangular Fuzzy-numbers:

Ardil (2021), described that the triangular Fuzzy number J_i has been defined by the triple $\{n_i, p_i, r_i\}$ and it is denoted as$J_i = \{n_i, p_i, r_i\}$, where $0 \leq n_i \leq p_i \leq r_i \leq 1$. Among them n_i indicates lower bound, p_i indicates the middle bound, and r_i indicates the upper bound. Membership function $\mu_T(l)$ is given by

$$\mu_T(l) = \begin{cases} 0 & ,l<n \\ (l-n)/(p-n) & ,n \leq l \leq p \\ (p-l)/(r-p) & ,p \leq l \leq r \\ 0 & ,l > p \end{cases}$$

Properties of Fuzzy-numbers:

Chiou and Tzeng (2002), Adril (2021), explain properties by considering two triangular Fuzzy sets, such as $\{n_1, p_1, r_1\}$ and $\{n_2, p_2, r_2\}$

Addition of two Fuzzy sets as $\{n_1, p_1, r_1\} \oplus \{n_2, p_2, r_2\} = \{n_1 + n_2, p_1 + p_2, r_1 + r_2\}$

Subtraction of two Fuzzy sets as $\{n_1, p_1, r_1\} \ominus \{n_2, p_2, r_2\} = \{n_1 - n_2, p_1 - p_2, r_1 - r_2\}$

Multiplication of two Fuzzy sets as $\{n_1, p_1, r_1\} \otimes \{n_2, p_2, r_2\} = \{n_1 n_2, p_1 p_2, r_1 r_2\}$

Division of two Fuzzy sets as $\{n_1, p_1, r_1\} \oslash \{n_2, p_2, r_2\} = \{n_1/r_2, p_1/p_2, r_1/n_2\}$

Multiplication of any real number b to Fuzzy sets as $b \otimes \{n_1, p_1, r_1\} = \{bn_1, bp_1, br_1\}$

Inverse of Fuzzy set, $\{n_1, p_1, r_1\}$ as $\{n_1, p_1, r_1\}^{-1} = \{\frac{1}{r_1}, \frac{1}{p_1}, \frac{1}{n_1}\}$

Interpretive structural modelling approach:

The ISM approach is invented by John N Warfield. In this method, the complex decision is into the structural matrix. It is used to analyze our decision supports. This approach is used for identifying the interrelationship among the barriers or enablers. This methodology uses a structure called a digraph to represent the interrelationship of the barriers graphically. In the initial stage, it might be done with a group of people and later on, it is done independently, (Rakesh Raut 2017).

There are several fruitful benefits to this approach (Prakash et al. 2020) Such as it is used in real-life situations, and if the variables are (10-15) then computational exercises can be minimized

Some of the disadvantages of this approach (Prakash et al. 2020) is, Experience of individuals and knowledge is essentially required to build contextual relationships.

Fuzzy-ISM:

While studying the ISM from different papers there are certain limitations as it is a qualitative approach. Some of the relationships are missing because in ISM methodology it will show whether one criterion is influencing the another or not but it is omitting the knowledge of whether it is high influencing or just influencing or not influencing is not told by this method. And this could be overcome with the help of FUZZY theory. The extension of ISM with FUZZY is known as FUZZY-ISM. In Fuzzy-ISM we are using triangular fuzzy numbers.

In this the linguistic scale we are considering five types of conditions those are, no influence between one barrier over the other, Very low influence between one barrier over the other, Low influence between one barrier over the other, High influence between one barrier over the other, and very high influence between one barrier over the other.

© IEOM Society International

For defuzzifying the triangular Fuzzy numbers after collecting responses from 6 experts, and taking the arithmetic mean of different response values. We are following the given below steps to get the crisp values.

Step-1:
Let fuzzy triangular numbers can be represented as f_{ij}= $[l_{ij}, m_{ij}, n_{ij}]$
Normalization:
U = max n_{ij}, L = min l_{ij} , Δ = U-L, $z_{lj} = \frac{l_{ij}-L}{\Delta}$, $z_{mj} = \frac{m_{ij}-L}{\Delta}$, $z_{nj} = \frac{n_{ij}-L}{\Delta}$
Step-2:
Evaluate normalized values of the right-hand side (R^*) and left-hand side (l^*)
$R^* = \frac{z_{nj}}{(1+z_{nj}-z_{mj})}$, $l^* = \frac{z_{mj}}{(1+z_{mj}-z_{lj})}$
Step-3:
Evaluate the total normalized crisp value, $z_j^{crisp} = \frac{l^*(1-l^*)+(R^*R^*)}{(1-l^*+R^*)}$
Step-4:
Evaluate the total crisp value as shown in the equation, $f_{ij}{}^n = \mathrm{L} + (z_j^{crisp} * \Delta)$
Step-5:
If there are "n", number of experts, then determine the average crisp value, $F_{ij}{}^n = \frac{f_{ij}{}^1+f_{ij}{}^2+\cdots f_{ij}{}^n}{n}$
As per the above equations, the driving powers and dependence power values of every barrier are evaluated. The obtained crisp values of different barriers are utilized to classify them into four regions and shown in a scatter plot graph this analysis is known as Fuzzy-MICMAC analysis (Srivastava Dashora 2021)

- Region 1: The variables that are located in this region are weak dependence and driving powers, which means those are not much affecting the system. These types of variables are called autonomous variables
- Region 2: The factors in this category are high reliance and low driving force. The variables in this region are called dependent variables.
- Region 3: The variables that come under this region have both driving and dependence on the strongest powers. The variables under this category should be handled carefully because a small effect on them may cause variation in other variables and also themselves. The variables in this region are called linkage variables.
- Region 4: The variables with strong driving and weak reliance power are located in this region. These variables are called independent variables.

4. Data Collection

Collection of data for these two methods is done by sending questionnaire to experts from different sectors. In A.H.P method there are 63 responses from sending 150 questionnaires in different sectors such as manufacturing, educational, general stores etc., and by applying this method it has been considered 12 important barriers among 21 for further analysis. In Fuzzy-ISM method it has been collected six responses from sending 15 questionnaires based on this method it has been found the interrelationship between the barriers tells the values of driving and dependence power for respective barriers.

5. Results & Discussion

According to responses filled by experts, the Judgement matrix, normalized matrix, and table for consistency ratio have been developed according to steps followed in A.H.P process that is explained in third chapter, displayed in Table 3, Table 4, and Table 5. These tables will give information only for the main categories.

Table 3. Pair-wise comparison matrix, Decision matrix

	strategic	**organizational**	**technological**	**ethical**
strategic	1.000	1.004	0.973	1.099
organizational	0.996	1.000	0.968	1.094
technological	1.028	1.033	1.000	1.130
ethical	0.910	0.914	0.885	1.000

Table 4. Normalized matrix

	strategic	**organizational**	**technological**	**ethical**	**X= Weight**

© IEOM Society International

strategic	0.254	0.254	0.254	0.254	0.254
organizational	0.253	0.253	0.253	0.253	0.253
technological	0.261	0.261	0.261	0.261	0.261
ethical	0.231	0.231	0.231	0.231	0.231

Table 5. Consistency ratio

	strategic	**organizational**	**technological**	**ethical**	**Y= Weighted sum value**	**Y/X**
strategic	0.254198083	0.254198083	0.254198083	0.254198083	1.016792	4
organizational	0.253070328	0.253070328	0.253070328	0.253070328	1.012281	4
technological	0.261360701	0.261360701	0.261360701	0.261360701	1.045443	4
ethical	0.231370888	0.231370888	0.231370888	0.231370888	0.925484	4

λ_{max}, for global categories is 4, and the consistency ratio is less than 0.1, so the obtained responses are valid. Similarly, the Judgement (Table 5), Normalization matrix, and consistency ratio- matrices are found for different sub-categories of every main category and checked for the consistency ratio. Calculated the global weights thereby ranking them according to their weights that are displayed in Table 6.

Table 6. Ranking of barriers using A.H.P results in effective implementation of I4.0

Statement of barrier	**Local weights**	**Global weights**	**Rank**
Unclear economic benefits of digital implementation	0.2103	0.0534	9
Lack of Research & development in digital SCM	0.1791	0.0455	11
Lack of Government support and policies	0.1851	0.0470	10
Lack of investments	0.2139	0.0543	7
Operational cost	0.2113	0.0537	8
Lack of organisation digital vision strategy	0.1286	0.0325	13
Lack of urgency	0.0875	0.0221	20
Continuous education of employee	0.1244	0.0314	17
Lack of skilled workers	0.1255	0.0317	15
Lack of management	0.1249	0.0316	16
Employee resistance in change for implementation of digitalization in SME's	0.1279	0.0323	14
Miss-aligned business objectives	0.1214	0.0307	19
Lack of top management support	0.0352	0.0089	21
Lack of training and trained staff	0.1242	0.0314	18
Lack of ICT and internet based network	0.3445	0.0900	1
Cyber resources	0.2694	0.0704	5
Ineffective Data management	0.1475	0.0385	12
Incompetent in swiftness of digital effectiveness	0.2384	0.0623	6
Cyber security risk	0.3231	0.0747	4
Legal or regulatory issues	0.3407	0.0788	2
Risk aversion	0.3361	0.0777	3

By studying the literature review, collecting the expert's opinions, and performing the A.H.P method we had finalized twelve important barriers to the execution of I4.0 in industries. These twelve barriers are (B01) Lack of information and communication technology infrastructure and internet-based network, (B02) Legal or regulatory issues, (B03) Risk aversion, (B04) Cyber security risk, (B05) Cyber resources, (B06) Incompetent in the swiftness of digital effectiveness, (B07) Lack of investments, (B08) Operational cost, (B09) Unclear economic benefits of I4.0, (B10) Lack of government support and policies, (B11) Lack of research and development in digital supply chain management, (B12) Ineffective data management (Figure 2 and Table 7).

Table 7. Driving and dependence power crisp values

	Driving powers				Dependence powers			
Barriers	z_{lj}	z_{mj}	z_{nj}	**Crisp value**	z_{lj}	z_{mj}	z_{nj}	**Crisp value**
Lack of Information technology infrastructure and internet-based network (B01)	6.357	9.214	11.928	3.367	6.854	9.285	12.014	2.721

© IEOM Society International

Legal or regulatory issues (B02)	9	13	17	2.670	6.285	9.142	11.813	3.562
Risk aversion (B03)	8.090	11.727	15.272	3.122	6.285	9.142	11.957	3.347
Cyber security risk (B04)	10.555	15	19.444	2.651	6.498	9.356	12.141	3.128
Cyber resources (B05)	8.9	12.9	16.9	2.724	6.570	9.428	12.242	2.821
Incompetent in the swiftness of digital effectiveness (B06)	10.222	14.666	19.111	2.710	6.427	9.284	12.141	2.710
Lack of investments (B07)	7.777	12.222	16.666	2.651	6.499	9.356	12.213	2.797
Operational cost (B08)	7.818	11.454	15.090	3.100	6.356	9.213	12.069	2.690
Unclear economic benefits of I4.0 (B09)	8.5	12.5	16.5	2.628	6.498	9.356	12.212	3.123
Lack of Government support and policies (B10)	10.666	15.111	19.333	2.871	6.428	9.285	12.141	2.729
Lack of Research & development in digital SCM (B11)	10.555	15	19.333	2.800	6.428	9.285	12.099	3.210
Ineffective Data management (B12)	9.888	14.333	18.777	2.651	6.642	9.5	12.356	2.867

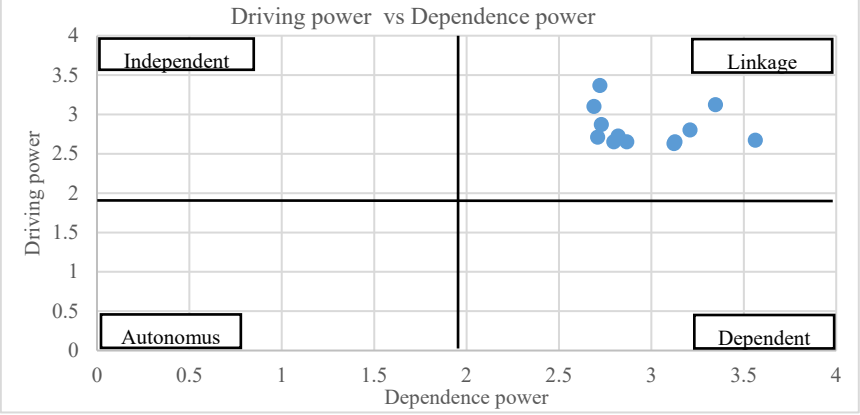

Figure 2. Scatter plot of driving power vs Dependence power

The scatter plot is drawn according to values obtained in driving and dependence power as per MICMAC analysis shown in Table 7, it is showing that all the twelve barriers are shown in quadrant 3 known as linkage variables. The main reason for falling all barriers in single quadrant is due to MICMAC analysis is done with the results of Fuzzy variables. In this Fuzzy study all type of relationships such as one barrier may influence to another barrier with no influence, very low influence, low influence, high influence, and very high influence are considered, so by the help of Fuzzy-ISM even there is a low influence between one barrier to other barrier but still the relationship between them is considered in analysis which may miss in normal ISM methodology.

Level Partitioning: The table is formed with the final reachability set is the sets obtained from the final reachability matrix, the antecedent set is the set of dependence power nothing but every column barrier of the final reachability matrix. If the reachability set is a subset of the antecedent set then those are considered for describing the level of barrier in the respective iteration. In the respective iteration (B08) operational cost, (B09) Unclear economic benefits of I4.0 act as level I barriers because those barriers reachability set is a subset of an antecedent set.

After level I partitioning the barriers that have occurred in level I should not consider for the next iteration and those barriers are eliminated from every subset of remaining barriers in the reachability set and antecedent set, Later the procedure follows as according to iteration 1. The barriers (B01) Lack of ICT and internet-based network, (B02) Legal or regulatory issues, (B03) Risk aversion, (B04) Cyber security risk, (B05) Cyber resources, (B06) Incompetent in the swiftness of digital effectiveness, (B07) Lack of investments, (B10) Lack of Government support and policies, (B11) Lack of Research & development in digital SCM, and (B12) Ineffective Data management is showing that reachability set and antecedent set are equal, this indicates that these barriers are partitioned at level II. If any barriers are not partitioned at level II then the procedure will continue for further iterations but in our case, all barriers are covered at partition level II.

Diagraph from the analysis:

© IEOM Society International

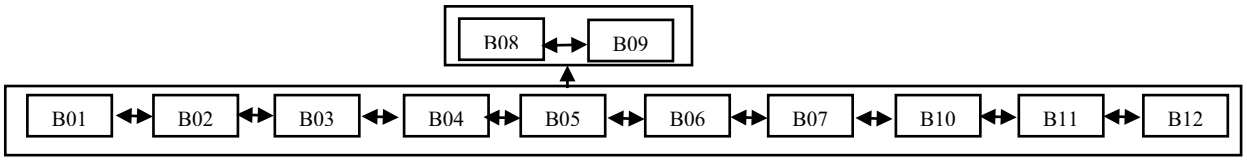

Figure 3. Diagraph

From the results obtained from level partitioning the above structure is an ISM hierarchical structure indicating barrier 1 to barrier 12 with respect to nodes from 1 to 12 (Figure 3). Finally based on this study one can able to know the basic knowledge of certain technologies of I4.0, the importance of technologies in SMEs, the economy growth of Indian government sector related to SMEs, the barriers that are act as hindrances for adopting I4.0 technologies in SMEs, Selection of most important barriers with the help of Analytical hierarchy process by collecting responses from different sectors such as manufacturing, general stores, educational sector, etc., Later done Fuzzy-ISM and MICMAC analysis is done by collecting responses for determining level partitioning from Fuzzy-ISM and graph from MICMAC analysis, which is used to demonstrate the relationship between one barrier over the other barrier. This study helps to give confidence about the barriers that are affecting in the execution of I4.0 technologies in industries.

6. Conclusions

The study involves finding the most important barriers among several barriers obtained from the literature review. After doing Analytical Hierarchy Process, we found the 12 important barriers. In the analysis, a fuzzy ISM model is employed to determine the contextual relationship between them, we found that all variables are linkage variables from the MICMAC analysis. The limitations in this research are for Fuzzy ISM it had need experienced professionals so we got a limited number of expert's opinions and for further improvement in results there may be a need for some more experts and also by giving the different weightage to every expert's opinion if there is a difference in experience and their respective fields. There is a tremendous scope in this research as future execution of I4.0 technologies in industries depends on this research, based on this research we can focus on the hindrances that are occurring while implementation of technologies of I4.0. Even though in this research it has been focused on the barriers but the solution of avoiding hindrances are not demonstrated in this paper, so this may be another field to improve the productivity of SMEs by finding the solutions to avoid hindrances.

References

Abiodun, T. F., Usage of drones or unmanned aerial vehicles (UAVs) for effective aerial surveillance, mapping system and intelligence gathering in combating insecurity in Nigeria. *African Journal of Social Sciences and Humanities Research*, *3*(2), 29-44, 2020.

Agrawal, P., Narain, R., & Ullah, I., Analysis of barriers in implementation of digital transformation of supply chain using interpretive structural modelling approach. *Journal of Modelling in Management*, 2019.

Ardil, C., Fighter Aircraft Evaluation and Selection Process Based on Triangular Fuzzy Numbers in Multiple Criteria Decision Making Analysis Using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). *International Journal of Computer and Systems Engineering*, *15*(12), 402-408, 2021.

Azeem, M., Haleem, A., Bahl, S., Javaid, M., Suman, R., & Nandan, D., Big data applications to take up major challenges across manufacturing industries: A brief review. *Materials Today: Proceedings*, 2021.

Azizi, A., *Applications of artificial intelligence techniques in industry 4.0*, Berlin, Germany: Springer, pp. 27-47, 2019.

Baig, M. I., Shuib, L., & Yadegaridehkordi, E., A Model for Decision-Makers' Adoption of Big Data in the Education Sector. *Sustainability*, *13*(24), 13995, 2021.

Bajpai, A., & Misra, S. C., Barriers to implementing digitalization in the Indian construction industry. *International Journal of Quality & Reliability Management*, 2021.

Bamburry, D., Drones: Designed for product delivery. *Design Management Review*, *26*(1), 40-48, 2015.

Ben-Daya, M., Hassini, E., & Bahroun, Z., Internet of things and supply chain management: a literature review. *International Journal of Production Research*, *57*(15-16), 4719-4742, 2019.

© IEOM Society International

Bienhaus, F., & Haddud, A., Procurement 4.0: factors influencing the digitisation of procurement and supply chains. *Business Process Management Journal*, 2018.

Chauhan, C., Singh, A., & Luthra, S., Barriers to industry 4.0 adoption and its performance implications: An empirical investigation of emerging economy. *Journal of Cleaner Production*, *285*, 124809, 2021.

Chiou, H. K., & Tzeng, G. H., Fuzzy multiple-criteria decision-making approach for industrial green engineering. *Environmental Management*, *30*(6), 0816-0830, 2002.

Dilberoglu, U. M., Gharehpapagh, B., Yaman, U., & Dolen, M., The role of additive manufacturing in the era of industry 4.0. *Procedia Manufacturing*, *11*, 545-554, 2017.

Dube, A. S., & Gawande, R. S., Analysis of green supply chain barriers using integrated ISM-fuzzy MICMAC approach. *Benchmarking: An International Journal*, 2016.

Dutta, G., Kumar, R., Sindhwani, R., & Singh, R. K., Digital transformation priorities of India's discrete manufacturing SMEs–a conceptual study in perspective of Industry 4.0. *Competitiveness Review: An International Business Journal*, 2020.

Ercan, T., Effective use of cloud computing in educational institutions. *Procedia-Social and Behavioral*, 2010.

Gupta, H., Kusi-Sarpong, S., & Rezaei, J., Barriers and overcoming strategies to supply chain sustainability innovation. *Resources, Conservation and Recycling*, *161*, 104819, 2020.

Haleem, A., Javaid, M., & Rab, S., Impact of additive manufacturing in different areas of Industry 4.0. *International Journal of Logistics Systems and Management*, *37*(2), 239-251, 2020.

Harputlugil, T., Analytic hierarchy process (AHP) as an assessment approach for architectural design: case study of architectural design studio, 2018.

Hermon, R., & Williams, P. A., Big data in healthcare: What is it used for?, 2014.

Jamwal, A., Agrawal, R., Gupta, S., Dangayach, G. S., Sharma, M., Sohag, M., & Zahid, A., Modelling of sustainable manufacturing barriers in pharmaceutical industries of Himachal Pradesh: an ISM-fuzzy approach. In *Proceedings of international conference in mechanical and energy technology* (pp. 157-167). Springer, Singapore, 2020.

Javaid, M., Haleem, A., Singh, R. P., & Suman, R., Significant applications of big data in Industry 4.0. *Journal of Industrial Integration and Management*, *6*(04), 429-447, 2021.

Jayant, A., & Azhar, M., Analysis of the barriers for implementing green supply chain management (GSCM) practices: an interpretive structural modeling (ISM) approach. *Procedia Engineering*, *97*, 2157-2166, 2014.

Kamble, S. S., Gunasekaran, A., & Sharma, R., Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry. *Computers in Industry*, *101*, 107-119, 2018.

Khan, M. I., Khan, S., Khan, U., & Haleem, A., Modeling the Big Data challenges in context of smart cities–an integrated fuzzy ISM-DEMATEL approach. *International Journal of Building Pathology and Adaptation*, 2021.

Kumar, A., & Kalse, A., Usage and adoption of artificial intelligence in SMEs. *Materials Today: Proceedings*, 2021.

Kumar, A., Mangla, S. K., & Kumar, P., Barriers for adoption of Industry 4.0 in sustainable food supply chain: a circular economy perspective. *International Journal of Productivity and Performance Management*, 2022.

Kumar, A., Sah, B., Singh, A. R., Deng, Y., He, X., Kumar, P., & Bansal, R. C., A review of multi criteria decision making (MCDM) towards sustainable renewable energy development. *Renewable and Sustainable Energy Reviews*, *69*, 596-609, 2017.

Kumar, P., Bhamu, J., & Sangwan, K. S., Analysis of barriers to Industry 4.0 adoption in manufacturing organizations: An ISM approach. *Procedia CIRP*, *98*, 85-90, 2021.

Kumar, R., Singh, R. K., & Dwivedi, Y. K., Application of industry 4.0 technologies in SMEs for ethical and sustainable operations: Analysis of challenges. *Journal of cleaner production*, *275*, 124063, 2020.

Kumar, S., Raut, R. D., Nayal, K., Kraus, S., Yadav, V. S., & Narkhede, B. E., To identify industry 4.0 and circular economy adoption barriers in the agriculture supply chain by using ISM-ANP. *Journal of Cleaner Production*, *293*, 126023, 2021.

Kumar, S., Suhaib, M., & Asjad, M., Analyzing the Barriers to Industry 4.0 Through Best-Worst Method. *International Journal of Performability Engineering*, *16*(1), 2020.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M., Industry 4.0. *Business & information systems engineering*, *6*(4), 239-242, 2014.

Linh, N. P. K., Kumar, V., & Ruan, X., Exploring enablers, barriers and opportunities to digital supply chain management in vietnamese manufacturing SMEs. *International Journal of Organizational Business Excellence*, *2*(2), 101-120, 2019.

Luthra, S., Mangla, S. K., Xu, L., & Diabat, A., Using AHP to evaluate barriers in adopting sustainable consumption and production initiatives in a supply chain. *International Journal of Production Economics*, *181*, 342-349, 2016.

© IEOM Society International

Majumdar, A., Garg, H., & Jain, R., Managing the barriers of Industry 4.0 adoption and implementation in textile and clothing industry: Interpretive structural model and triple helix framework. *Computers in Industry*, *125*, 103372, 2021.

Mathiyazhagan, K., Govindan, K., NoorulHaq, A., & Geng, Y., An ISM approach for the barrier analysis in implementing green supply chain management. *Journal of cleaner production*, *47*, 283-297, 2013.

Nimawat, D., & Gidwani, B. D., Prioritization of barriers for Industry 4.0 adoption in the context of Indian manufacturing industries using AHP and ANP analysis. *International Journal of Computer Integrated Manufacturing*, *34*(11), 1139-1161, 2021.

Parmar, N. K., Analysis of barriers for implementing green supply chain management in small and medium sized enterprises (SMEs) of India. *International Journal of Humanities and Management Sciences*, *4*(3), 219-223, 2016.

Patel, D. V., & Patel, A. S., FACTORS AFFECTING IMPLEMENTATION OF DIGITALIZATION IN INDIAN CONSTRUCTION INDUSTRY, 2020.

Peillon, S., & Dubruc, N., Barriers to digital servitization in French manufacturing SMEs. *Procedia CIRP*, *83*, 146-150, 2019.

Pejić Bach, M., Krstić, Ž., Seljan, S., & Turulja, L., Text mining for big data analysis in financial sector: A literature review. *Sustainability*, *11*(5), 1277, 2019.

Rathod, C. B., Ranpura, D., & Patel, C., SMEs and economic growth in India: A comparative study. In *International Conference on "Developing Indian Economy as an Engine for Job Creation: Role of Make in India, Digital India, Start-up India and Skill India*, 2016.

Rauschnabel, P. A., He, J., & Ro, Y. K., Antecedents to the adoption of augmented reality smart glasses: A closer look at privacy risks. *Journal of Business Research*, *92*, 374-384, 2018.

Said, K. O., Onifade, M., Githiria, J. M., Abdulsalam, J., Bodunrin, M. O., Genc, B., & Akande, J. M., On the application of drones: a progress report in mining operations. *International Journal of Mining, Reclamation and Environment*, *35*(4), 235-267, 2021.

Srivastava, A., & Dashora, K., A Fuzzy ISM approach for modeling electronic traceability in agri-food supply chain in India. *Annals of Operations Research*, 1-19, 2021.

Stentoft, J., Adsbøll Wickstrøm, K., Philipsen, K., & Haug, A., Drivers and barriers for Industry 4.0 readiness and practice: empirical evidence from small and medium-sized manufacturers. *Production Planning & Control*, *32*(10), 811-828, 2021.

Thakkar, J., Deshmukh, S. G., Gupta, A. D., & Shankar, R., Selection of third-party logistics (3PL): a hybrid approach using interpretive structural modeling (ISM) and analytic network process (ANP). In *Supply Chain Forum: An International Journal* , Vol. 6, No. 1, pp. 32-46, 2005.

Vemula, H. L., Khichi, T., Murugesan, G., Valderrama-Plasencia, L., Salazar-Gonzales, M., & Ventayen, R. J. M., ROLE of cloud computing and its impact on consumer behavior in financial sector. *Materials Today: Proceedings*, *51*, 2190-2193, 2022.

Vigneshvaran, R., & Vinodh, S., Development of a structural model based on ISM for analysis of barriers to integration of lean with industry 4.0. *The TQM Journal*, 2020.

Biographies

K. Pavan is graduated in Mechanical engineering from Sagi Rama Krishnam Raju engineering college, Bhimavaram in 2019, and had a project track wheelchair project in the final year of B.Tech. Currently in the final year of Post-graduation under the stream of Industrial engineering from the DR. B.R Ambedkar National Institute of Technology Jalandhar, India.

Dr. Anish Sachdeva is a Professor in the Industrial and Production Engineering Department at NIT Jalandhar, India. His areas of interest are Reliability and Maintenance Engineering, supply chain management, Optimization and Simulation of Production Systems, Quality Management. He obtained his B.Tech from Dr B R Ambedkar National Institute of Technology, Jalandhar, and M.Tech from Guru Nanak Dev Engineering College Ludhiana and Ph.D. from IIT Roorkee (India). He has guided 70 M Tech and 16 PhD students. He has over 150 publications in international and national journals and proceedings of international conferences to his credit. He has organized seven international conferences at NIT Jalandhar as Organizing Secretary and more than 20 short-term courses in his area of expertise.

Vinay Kumar Sharma is research scholar in the department of Industrial and Production engineering at NIT JALANDHAR. He has numerous publications in journal of repute. He has prior experience of teaching of 3 years before starting his PhD. He has also got industrial experience in Research and development department in automotive sector. He is an active participant of national and international conferences. He has also attended various seminars and

© IEOM Society International

workshops for knowledge and skill enhancements. His research interests are in Supply chain. Sustainability, Quality management, Lean Manufacturing, Project management etc.

© IEOM Society International