Barriers of Industry 4.0 Implementation in Developing Economy: A MICMAC Analysis

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***Abstract*— Industry 4.0 is started in Germany then adopted by countries around the world. Developed economies have already taken the initiative in this direction by different action plans. The acceptability of Industry 4.0 by developed economies presents significant competition to the developing economy as it may be result in job migration and business unbalance. For maintain global manufacturing competitiveness, each of the developing economy needs to participate in this industrial revolution. But now there are lots of barrier in implementation in developing economy. This paper makes an attempt to identify the key barriers of implementation of Industry 4.0 and model their interrelations to measure the effectiveness under framework. Implementation barriers interrelation is not available in literature and hence it is important to identify and measure the interrelations among those to arrive at few driving barriers among many. The paper uses Delphi embedded fuzzy interpretive structural modeling to model the interrelationship. Further MICMAC analysis is used to different barriers into groups according to their driving power and dependence in the system.**

Keywords— Industry 4.0; Implementation Barrier; MICMAC Analysis

I. INTRODUCTION

Industry 4.0 is important term that exemplifies the possibility of the fourth Industrial Revolution. This fourth Industrial Revolution is as vital as the mechanical revolution that happened in mid of the 1800's. Industry 4.0 has been developed in Germany, but now acceptance increased across the world. [1]

The industrial sector is important to every country's economy and remains the driver of growth and employment. Industry, which in this context focuses on manufacturing, provides added value through the transformation of materials into products [2]. The term "Industry 4.0" became publicly known in 2011, when an initiative called "Industry 4.0" where an association of representatives from business, politics, and academia promote the idea as an approach to strengthen the competitiveness of German manufacturing industry. Germany has one of the most competitive manufacturing Industries in the world and is a global leader in the manufacturing equipment sector. Since the German federal government announced Industry 4.0 as one of the key initiatives of its high-tech strategy in 2011, the topic of Industry 4.0 has become famous among many companies, research centers, and universities. Numerous academic publications, practical articles, and conferences have discussed this topic . The German Federal Government presents Industry 4.0 as a new, emerging structure in which manufacturing and logistics systems in the form of Cyber-Physical Production Systems (CPPS) intensively use the globally available information and communications network for an extensively automated exchange of information and in which production and business processes are matched [4].

As the term "Industry 4.0" is not well-known outside the German-speaking area, it is worth looking at comparable ideas from a global perspective. Some commentator promotes a similar idea under the name of cyber physical systems, smart factory, smart production, machine-to-machine, advanced manufacturing, internet of things, internet of everything or industrial internet.

Industry 4.0 or fourth industrial revolution also refers to the next phase in a digitization of the manufacturing sector where the Internet of Things (IoT) looks to play a huge role that have the potential to feed information into it and add value to manufacturing industry to realize a low-volume, high-mix production in a cost-efficient way. It also involves the management and organization of the entire value chain process of the manufacturing industry [3].

Various organizations have been advocating Industrial Internet of Things and Industry 4.0 concepts to create smarter factories. Meanwhile, according to, the idea of Industry 4.0 includes a wide variety of devices, from smart phones, gadgets, televisions and watches to household appliances, which are becoming ever more flexible and intelligent. The devices are increasingly able to communicate with one another or to data sources via the Internet [3].

Industry 4.0 is a kind of transformation. A developed economy with rich experiences in the application and adoption of related technologies will have higher ability in technological innovation. An developed economy will have higher innovative capability when knowledge can be shared more easily. Technological advancement can be achieved with higher transferability [5]. It is easy to share technological transfer or share technological knowledge with higher explicitness. But with the developing economy it's difficult to adopt new technology and advancement due to different reasons and aspects, which is dependent on different area like capital, demand, geographical location.

II. METHODOLOGY

To cover relevant barriers for implementation of Industry 4.0, authors took advantage of five publication databases (CiteSeerX, ACM, AISeL, EBSCOhost, Emerald Insight) and Google Scholar.

A. Delphi Technique

The Delphi Technique was designed to gather input from participants without requiring them to work face to face. Often, the process is used to find consensus among experts who have differing views and perspectives [7].. The Delphi Technique enables group problem-solving using an iterative process of problem definition and discussion, feedback, and revisions. This research tool allows researchers to combine the reports or testimony of a group of experts into one, useful statement through an iterative convergence method. Delphi method is widely used by researchers because of its effectiveness in studies related to structuring the process of communication and in developing consensus.

B. Interpretive Structural Modeling

Interpretive structural modeling ISM is an interactive learning process. In this technique, a set of different directly and indirectly related elements are structured into a comprehensive systematic model [9]. The model so formed portrays the structure of a complex issue or problem in a carefully designed pattern implying graphics as well as words. The outcome of the model is a directed graph that captures the overall structure of the system and provides a hierarchy among the factors with respect to their driving power in the system. MICMAC analysis captures the position of the performance barriers or factors in a two dimensional plane with respect to the driving power and dependence of the barriers within the system [12]. Embedding fuzzy sets with MICMAC captures the ambiguity in such relationship in a better way by providing a scale between 0 and 1.

III. BARRIERS IN IMPLEMENTATION OF INDUSTRY 4.0

Based on the above literature and after consulting the experts for their valuable input, seven barriers are identified those are present across multiple research works. Table 1 demonstrates these seven barriers with the most prominent literatures supporting their existence in the implementation of Industry 4.0. Once the barriers were identified a three stage Delphi process was conducted to get a convergence among the expert opinions.

TABEL I: BARRIERS FOR IMPLEMENTATION OF INDUSTRY 4.0

S.No.	Barriers	References
1	Return on investment (ROI)	[1],[2]
2	Skilled Work Force(SWF)	[4],[6]
3	I T infrastructure(ITI)	[10],[12]
4	Upgraded Technological Advancement(UTA)	[13],[15]
5	Capital Requirement (CR)	[18],[16]
6	Financial Assistance (FA)	[5],[6]
7	Software Development(SD)	[11],[20]

A. Delphi –Fuzzy ISM and MICMAC Framework

The objective behind using ISM and Fuzzy MICMAC is to understand the interrelationship among the barriers for implementation.

Structural Self-Interaction Matrix (SSIM)

The structural self-interaction matrix (SSIM) is created with the help of expert opinion on the contextual relationship among the barriers. Table 2 demonstrates the SSIM together with the power of the interrelations. To measure the relationship "leads to" is used along with four symbols A, B, C and D to denote the direction of relationship among the barrier i and barrier j.

A.: Barrier t i leads to component j
B.: Barrier j leads to component i
C.: Barrier i and component j leads to each other
D.: Barrier i and component j has no relation

TABEL II: STRUCTURAL SELF-INTERACTION MATRIX (SSIM)

Barriers	2	3	4	5	6	7
Return on investment	A(.8)	A(.5)	B(.7)	B(.6)	B(.8)	D(0)
Skilled Work force		B(.4)	B(.6)	B(.8)	B(.4)	B(.6)
I T infrastructure			B(.6)	B(.7)	B(.9)	A(.5)
Upgraded Technological Advancement				A(.8)	B(.7)	A(.7)
Capital Requirement					C(.6, .8)	A(.7)
Financial Assistance						A(.8)
Software Development						

B. Reachability Matrix

The reachability matrix is created by converting the SSIM to a binary matrix by substituting A, B, C and D as 0 or 1 as per the case following the rules:

If the (i,j) entry of the SSIM is A, the (i,j) entry in the reachability matrix will be 1 and the (j,i) entry will be 0.
If the (i,j) entry of the SSIM is B, the (j,i) entry in the reachability matrix will be 1 and the (i,j) entry will be 0.
If the (i,j) entry of the SSIM is C, both the (i,j) entry and the (j,i) entry in the reachability matrix will be 1.
If the (i,j) entry of the SSIM is D, both the (i,j) entry and the (j,i) entry in the reachability matrix will be 0.
The reachability matrix is shown in Table 3.

TABEL III: REACHABILITY MATRIX

Barriers	1	2	3	4	5	6	7
Return on investment	1	1	1	0	0	0	0
Skilled Work force	0	1	0	0	0	0	0
I T infrastructure	0	1	1	0	0	0	1
Upgraded Technological Advancement	1	1	1	1	1	0	1
Capital Requirement	1	1	1	0	1	1	1
Financial Assistance	1	1	1	1	1	1	1
Software Development	0	1	0	0	0	0	1

C. *Level Partition*

From the reachability matrix the 'reachability set' and 'antecedent set' for each component are captured. The reachability set of a component is the set of all barriers it has influenced including itself. Whereas antecedent set consists of the component itself along with those who have influenced it in the system. Further an intersection set is also derived for all the barriers to generate levels

TABEL IV: REACHABILITY MATRIX WITH DRIVING POWER AND DEPENDENCE

Component	1	2	3	4	5	6	7	Driving Power
Return on investment	1	1	1	0	0	0	0	3
Skilled Work force	0	1	0	0	0	0	0	1
I T infrastructure	0	1	1	0	0	0	1	3
Upgraded Technological Advancement	1	1	1	1	1	0	1	6
Capital Requirement	1	1	1	0	1	1	1	6
Financial Assistance	1	1	1	1	1	1	1	7
Software Development	0	1	0	0	0	0	1	2
Dependence	5	9	8	6	8	8	12	

The component for whom the reachability set and the intersection set are same, is the highest level component in the ISM hierarchy that has minimum influence on the system. Table 5 shows how the partition is made in iteration 1. Once the component is identified it is removed from the list and the same exercise is repeated to identify the next level element. The process continues till the levels of each component are found.

TABLE V: LEVEL PARTITION IN ITERATION 1

Barrier	Reachability Set	Antecedent set	Intersection set	Level
1	1,2,3	1,4,5,6	1	
2	2	1,2,3,4,5,6,7	2	I
3	2,3,7	1,3,4,5,6	3	
4	1,2,3,4,5,7	4,6	4	
5	1,2,3,5,6,7	4,5,6	5,6	
6	1,2,3,4,5,6,7	5,6	5,6	
7	2,7	3,4,5,6,7	7	

Table 6 shows the complete level partitions. These levels help create the digraph representing causality or interrelationship.

TABLE VI: LEVEL PARTITION IN ITERATION 1

Iteration	Barrier	Reac-habili ty	Antecedent set	Intersection Set	Level
1	2	2	1,2,3,4,5,6, 7	2	I
2	7	7	3,4,5,6,7	7	II
3	3	3	1,3,4,5,6	3	III
4	1	1	1,4,5,6	1	IV
5	5,6	5,6	4,5,6	5,6	V
5	4,5,6	4,5,6	5,6	5,6	V
6	4,5	4,5	4,6	4	VI

D. *MICMAC analysis*

The objective of MICMAC analysis is to create clusters among the barriers with respect to their driving power and dependence in the system. Here the inclusion of fuzzy scale captures the strength of the relations in a better way. Based on the analysis all the barriers are grouped into four clusters namely 'autonomous', 'independent', 'dependent' and 'linkage'. Autonomous barriers are those with less dependence and less driving power. Independent barriers are those with high driving power but less dependence. Dependent barriers are just its opposite where the linkage barriers are those with high dependence and driving power. These are the most sensitive barriers in the system.

IV. RESULT AND DISCUSSION

The objective of this ISM model is to develop a hierarchy of barriers considered in this study. This directed graph helps us understand the interrelations among the barriers. Fig. 2 demonstrates the hierarchy including the direction of the relations From Figure 2 we can see that upgraded technological advancement drive the other barriers.
Both the capital requirement and financial assistance are at the same level and drive others in the system where skilled work force is the most dependent component is the system.

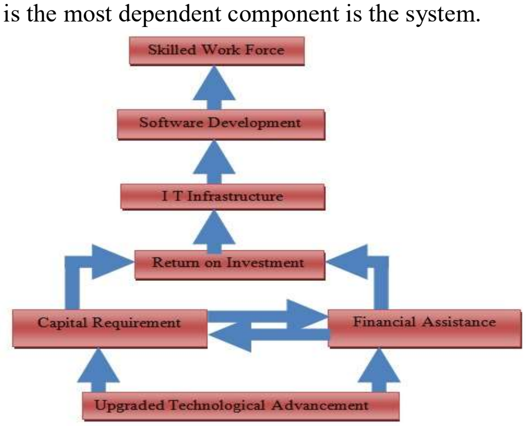

Fig. 1. The Hierarchy of Barriers

After considering the power of the relationships using fuzzy numbers, one can see from fig. 3 that financial assistant and capital requirement are the linkage barriers contributing maximum to the system. They are the most volatile barriers and affect the system more than the others. Upgraded technological advancement on the other hand is independent and has less dependence with a higher driving power.

Software development is a dependent component whereas the other three are autonomous in nature.

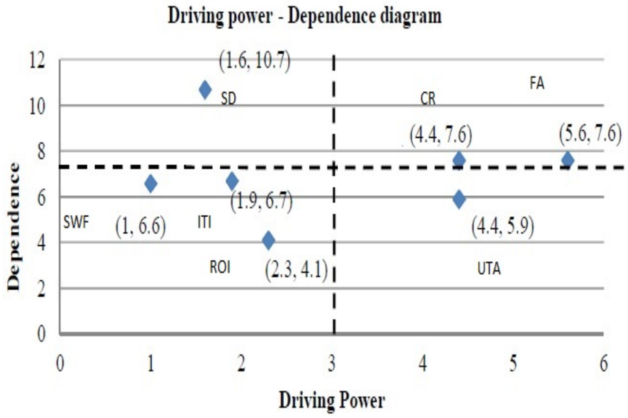

Fig. 2. Fuzzy MICMAC Analysis

VI. Conclusion

This study makes an attempt to identify and understand the interrelationships among barriers for implementation in Industry 4.0. This study identifies the importance of upgraded Technological Advancement, Financial assistant, Capital requirement as the three very important aspects that barriers in implementation. Though multiple barriers exist, it is good enough to focus on these three instead of trying to monitor every other barrier in the implementation. The inclusion of fuzzy numbers help capture the degree of driving power and dependence in the system more accurately and thus provides a better insight.

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