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EVALUATING CHALLENGES TO IMPLEMENTATION OF INDUSTRY 4.0 USING ANALYTICAL HIERARCHICAL PROCESS (AHP) AND INTERPRETIVE STRUC TURAL MODELING (ISM).

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Abstract

This analysis seeks to recognize primary barriers to Industry 4.0 strategies and evaluate them in order to prioritize them for successful Industry 4.0 implementation using Analytical Hierarchical Process (AHP) and Interpretive Structural Modeling (ISM). Industry 4.0 plays an important role for supply chain sustainability in developing markets, as seen from the lens of the Indian manufacturing industry. The following study will help practitioners, policymakers, regulatory bodies, and managers gain a better perspective of Industry - 4.0 implementation and eliminate the obstacles that may arise when implementing them for supply chain sustainability.

Keywords – Industry 4.0, Sustainable Supply Chain Management (SSCM), Internet of Things(IoT), Interpretive Structural Modeling (ISM), Analytical Hierarchical Process (AHP).

I. INTRODUCTION

Industry- 4.0 is the most trending concept in industries (Hermann et al., 2016). Recently, industries are willing to implement sustainability concepts in it's industrial facilities (Mangla et al., 2015; Govindan et al., 2016; Luthra et al., 2017). But on the other side, industrial facilities are struggling to balance the dynamic demands of customers and market and also in maintaining a sustainable development in working (Stock and Seliger, 2016). For developing a creative business module, organizations are implementing latest techniques like 3D printing, Internet of Things (IoT), Data Analytics, Industry 4.0 (Almada-Lobo, 2016). Which is significantly helping in changing the flow of value chain (Tjahjono et al., 2017). Industry- 4.0 with respect to sustainability surrounded developments help organizations to implement ecological safeguarding and control methods and to amalgamate method security, for example resource efficacy, employee and social benefit, latest and flexible process measures along it's value chains. The development of 4th Industrial revolution has helped in humongous industrial development, but it has also hampered the sustainability of recent production amendments (Hermann et al., 2016; Liao et al., 2017). Which shall also lead to earthly imbalances w.r.t. greater resource utilization, global warming, climatic issues, and greater energy demands. Along with this, faster industrialization also leads to depleted health issues and security of workers. With this reference, production manufacturing chains are required to be in synchronization with ecologically, socially and financially in amending latest methodologies. The highest number of researches in Industry-4.0 took into consideration the production facilities in context and did not bother about the supply chain system.

Industry- 4.0 dynamics can convert any manufacturing environment or value chain to a developed production facility mainly relied on cyber physical network of interconnected elements. Which permits trading processes and activities to amalgamate and allow production firms to be more malleable, cost effective, and environmentally concerned (Wang et al., 2016). From the point of view of an organizational value chain, Industry- 4.0 includes various exceptions such as information efficiency and reliability, unemployment, dynamic behavior issues, less human activities, and more environmental repercussions.

II. INDUSTRY 4.0

If we consider the recent developing years, production facilities and systems have been majorly drawn towards the introduction of the Internet of Things (IoT) and Cyber Physical Network System Concepts (Wollschlaeger et al., 2017). The 4th Industrial revolution has attracted immeasurable research along the people all over the world (Liao et al., 2017). Through the implementation of new communication and information technology and the convergence of industrial development, data networks, and latest manufacturing developments such as intelligent processing, human-computer interaction, 3₹-D printing, and automated operations, the fourth revolution lays the foundations for Industry 4.0. (Basl, 2017; Khan et al., 2017; Duarte and Cruz-Machado, 2017). Industry- 4.0, also known as "smart manufacturing" or "integrated industry," contains the potential to affect the complete sector with regard to product design, development, and execution, among other aspects. (Hofmann and Rüsch, 2017). It also defines more accurate methods to control the manufacturing systems in comparison with traditional systems. Industry- 4.0 is the extended process in an elaborated methodology of development, a complete modern skill set relied on the implementation of Cyber- Physical Systems (CPS) (Grieco et al. 2017). Indeed, the development of the IoT and Big Data has resulted in the formation of Industry-4.0 as a result of the ongoing development.

As an initial understanding, we can elaborate Industry 4.0 as below:

• Systems and services may be linked in a range of ways, such as through the internet or other networking technologies like block chain technology.

• Without human intervention, digital setups enables self controlled and self-enhanced build up of products as well as services, along with logistics (self-performing manufacturing systems based on transparency and predictive power). Decentralised control is inculcated to manage and control value chain networks, while systematic elements (such as manufacturing plants or transportation vehicles) make auto controlled actions. (Hofmann and Rüsch 2017).

III. SUSTAINABLE SUPPLY CHAIN MANAGEMENT (SSCM)

Accordingly SSC Management (SSCM), it is "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements". (Seuring & Müller, 2008). Sustainable Supply Chain Management (SSCM) is implemented in industries, based on the Triple Bottom Line (TBL) (Gold 2010; Linton et al., 2007; Seuring & Müller, 2008; Beske & Seuring, 2014; Seuring, 2011). The three divisions of the Triple Bottom Line (TBL) are Environment, Social, and Economic. The below is a list of the three branches: A Structure for Sustainable Supply Chain Management

Environment: It tackles topics such as natural resource degradation, ozone layer loss, and conformity with standards, among others.

Society: applies to work diversity (child labour, slave labour, etc.), equal opportunity, civil rights, and so on.

Economics: is concerned with consistency, monetary progress, risk control, and return on investment (ROI), among other aspects.

IV. CHALLENGES TO IMPLEMENTATION OF INDUSTRY 4.0 FOR SUPPLY CHAIN SUSTAINABILITY

This study evaluates the 20 key challenges to implementation of Industry 4.0 for Supply Chain Sustainability and further these challenges are prioritised with the use of two mathematical models that are Analytical Hierarchical Process (AHP) and Interpretive Structure Modelling (ISM).

Table 1: 20 Key Challenges to Implementation of Industry 4.0

BARRIERS	CONCEPT
Lack of governmental policy and support. BRICS Business Council, 2017	In India, there are clearly no specific government guidelines or guidance on industry 4.0. Governments are still uncertain about the potential implications of Industry 4.0.
Poor research & development on Industry 4.0 adoption. Schmidt et al.,2015; Hermann et al., 2016	Corporate organisations are having difficulties implementing Industry 4.0 due to a lack of accurate decision-making processes during this business transition.
Unclear economic benefit of digital investment. Kiel et al., 2017; Marques et al., 2017	One of the main challenges to Industry 4.0 strategies for achieving supply chain efficiency is the lack of a well identified return on investment.
Inadequate management support and dedication. Gökalp et al., 2017; Savtschenko et al., 2017; Shamim et al., 2017	For Industry- 4.0-driven sustainable growth, organisations can concentrate on developing their skills in terms of workforce preparation and development, as well as information management systems.
Lack of digital culture. Ras et al., 2017; Schuh et al., 2017	Industry- 4.0 is multi disciplinary in nature, necessitating the use of digitization to link various subjects of a network cluster.
Financial constraints. Dawson 2014; Theorin et al. 2017; Nicoletti, 2018	Financial limitations are seen as a significant obstacle to market enterprises improving their skills in consideration to specialised tools and devices, services, or viable methods advances in Industry 4.0.
Absence of Inter and Intra Firm Connection. D. Kiel et al. 2017	The technological transformation and modernisation of production facilities, as well as the harmonisation of mechanical, electrical, wireless, and connected parts, are all needed for intra-firm connectivity.
Non Standardized Communication Protocols. D. Kiel et al. 2017	Representatives from the organization are worried about the introduction of immature technology, which may threaten usable product protection and process efficiency, resulting in output downtimes.
Incompetent Business Models. Lee et al., 2014; Duarte and Cruz- Machado, 2017; Pfohl et al., 2017	To succeed internationally, the new industrial structure necessitates a highly customized and scalable climate. Industries must adapt modern business models in this regard.
Low Understandability. Almada-Lobo,2016; Hofmann and Rüsch, 2017	For a precise concept of Industry 4.0, the literature explicitly calls for strongly organised and oriented analysis.

Inadequate Training Methods. Erol et al. 2016; Ras et al., 2017	To embrace digitization in the manufacturing context, workers must be educated in the fundamental processes, their interdependencies, and data analysis.
Long Term Employee Loyalty. D. Kiel et al. 2017	The transformational process necessitates the establishment of a flexible business culture guided by the desire to follow a new manufacturing model.
Legal Issues. Schröder, 2016; Müller et al., 2017	Industry- 4.0 seeks to create a network that links different computers, sensors, services, and people to the cloud and shares data. Several complicated legal issues can occur as a result of this cyber-physical network.
Security issues. Sommer, 2015; Wang et al., 2016; Pereira et al., 2017	Supply chain networks have underlying security flaws that attackers take advantage of. Also the security flaws begins with the provider, who is prone to cyber scams and the theft of sensitive passwords, exposing a large amount of data.
Poor coordination and collaboration. Dawson 2014; Theorin et al. 2017; Nicoletti 2018	With greater compatibility problems of hardware and software, which includes standard interfaces, and data synchronization to achieve better synchronization with vendors, teamwork and cooperation with suppliers is required for improved communication setups.
Lack of Customer Supplier Involvement. D. Kiel et al. 2017	It involves not only main stakeholders, but also consumers and vendors, who must be more closely engaged in the value creating process. In this sense, supplier management is particularly relevant.
Incompetent global standards and data sharing protocols. Branke et al., 2016	In order to succeed, industries must adhere to global norms and data exchange protocols.
Poor existing data quality. Santos et al., 2017	One of the most important requirements for effective Industry- 4.0 implementation is data accuracy. Several computers, cameras, production processes, and services are integrated in Industry- 4.0, culminating in big data.
Insufficient infrastructure and internet based networks. Leitão et al., 2016; Bedekar, 2017; Pfohl et al., 2017	In the context of India, internet-based innovations are not equally recognised in urban and rural areas, which can stymie long-term business development.
Incompatible technological platforms. Zhou et al., 2015	Technology convergence is critical for improved collaboration and increased efficiency. Industries are struggling to provide a scalable interface that can integrate a variety of heterogeneous components.

V. METHODOLOGY

V.I Analytical Hierarchical Process (AHP)

AHP was first proposed by Saaty (1980). Ravi et al. (2005) addressed that AHP is a popular multiple criteria decision-making technique that combines qualitative with quantitative criteria. It ranks the potential suppliers in a hierarchical system (Faisal et al., 2006; Thakkar et al., 2008). Moreover, it is a group decision making technique that helps decision makers find the best criteria for reaching the goal.

AHP is better than other multi-criteria techniques because it is designed to work with tangible as well as non-tangible criteria, especially if subjective judgements of different experts' contribute an important part of decision making (Saaty, 1990; 2000; 2008; Dalalah, Hayajneh, & Batieha, 2011). To prioritise the criteria and their sub-criteria which are already identified through an extensive literature review and all supportive literatures have been put in Table 1. After the development of the model, we break our objective in the hierarchy decision-making process (Viswanadhan, 2005). To collect the data a pairwise comparison questionnaire has been developed. Experts from industry and academics have been selected on the basis of their experience and research work and data have been collected through personal interview. The data have been collected and synthesised in Microsoft Excel and then analysed.

V.II Interpretive Structural Modelling (ISM)

ISM was first proposed by J. Warfield in 1973 to analyze the complex social and economic systems. It is a computer-based learning process that enables individuals or groups to develop a roadmap to unravel the complex relations between the criteria involved in complex situations. The basic idea is to use practical experience and knowledge of experts to solve a complicated system with several subsystem elements and construct a multilevel structural model. Essentially, the method involves taking a set criteria, comparing them in a defined binary relation, and constructing a reachability matrix from the comparison. ISM is interpreted based on the group's judgment and decision whether and how the system's elements are linked (Ahuja et al. 2009). It is structured and designed on the foundation of the relationship and the final structure is exploited from a complex set of system variables. It is also a model as the final relationship is illustrated in a directed graph model.

Table 2: Classification of Criteria and Sub- Criteria

CRITERIA	SUB CRITERIA
STRATEGY	Lack of Government Support & Policies
	Poor R&D on Implementation of Industry 4.0
	Unclear Economic Benefits

OPERATIONS	Inadequate Management Support
	Lack of Digital Culture
	Financial Constraints
ORGANISATIONAL AND PRODUCTION FIT	Absence of Intrs and Inter Firm Connection
	Non Standardised Communication Protocols
EMPLOYEE QUALIFICATION AND ACCEPTANCE	Incompetent Business Models
	Inadequate Training Methods
	Low Understandability
	Long Term Employee Loyalty
TECHNOLOGICAL IMPOSITION	Incompetent Global Standards and Sharing Protocols
	Poor Existing Data Quality
	Insufficient Infrastructure and Internet based Networks
	Incompetent Technological Platform
IMPLEMENTATION	Legal Issues
	Poor Coordination and Collaboration
	Security Issues
	Lack of Customer Supplier Involvement

VI. RESULTS

Evaluating the above 20 key challenges with the use of 2 different methods namely Analytical Hierarchical Process (AHP) and Interpretive Structural Modeling (ISM) helped us to prioritise them in two different ways and according to two different set of survey and analysis.

Table 3: Prioritization of the sub criteria after applying AHP

SUB CRITERIA	LOCAL RANK	GLOBAL RANK
Lack of Government Support & Policies	**3**	**18**
Poor R&D on Implementation of Industry 4.0	**2**	**15**
Unclear Economic Benefits	**1**	**13**
Inadequate Management Support	**3**	**19**
Lack of Digital Culture	**2**	**14**
Financial Constraints	**1**	**12**
Absence of Intra and Inter Firm Connection	**1**	**1**
Non Standardized Communication Protocols	**2**	**10**
Incompetent Business Models	**3**	**7**
Inadequate Training Methods	**1**	**3**
Low Understandability	**2**	**5**
Long Term Employee Loyalty	**4**	**8**
Incompetent Global Standards and Sharing Protocols	**4**	**20**
Poor Existing Data Quality	**3**	**17**
Insufficient Infrastructure and Internet based Networks	**2**	**16**
Incompetent Technological Platform	**1**	**11**
Legal Issues	**4**	**9**
Poor Coordination and Collaboration	**3**	**6**
Security Issues	**1**	**2**
Lack of Customer Supplier Involvement	**2**	**4**

Table 4: Prioritization of the criterion after applying AHP

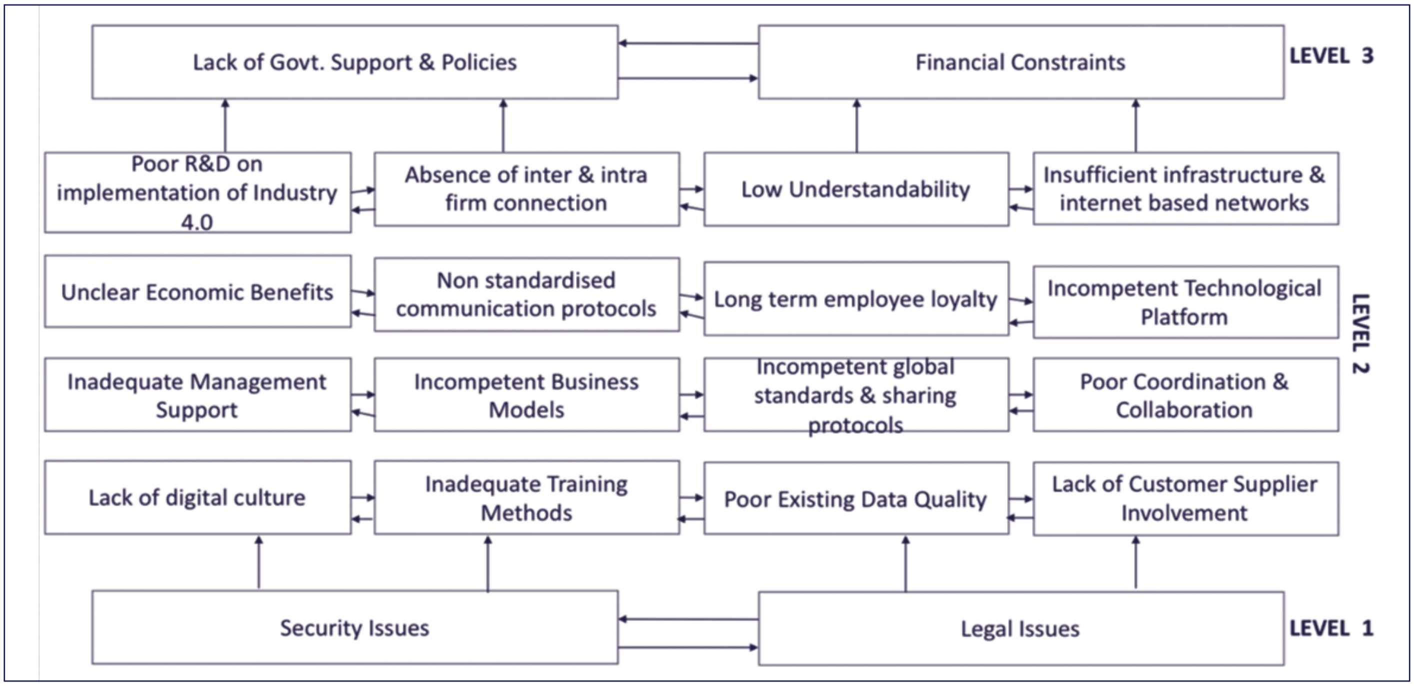
CRITERIA	RANK
STRATEGY	6
OPERATIONS	5
ORGANIZATIONAL AND PRODUCTION FIT	4
EMPLOYEE QUALIFICATION AND ACCEPTANCE	2
TECHNOLOGICAL IMPOSITION	3
IMPLEMENTATION	1

While implementing **Analytical Hierarchical Process (AHP)** we concluded that amongst the major criterion as shown in in Table.4 which were analysed **Implementation** is at the top priority of the major challenges that are to be primarily analysed and worked upon. And from the sub criteria challenges as shown in Table.3 the most effective one which needed to be eliminated initially is **Absence of Intra and Inter Firm Connection.** Working upon them according to the ranks obtained will further help in the successful implementation of Indsutry 4.0 in consideration with maintaining Supply Chain Sustainability. Whereas with the help of **Interpretive Structural Modeling (ISM)** we were able to identify the interdependence of all the sub criterion shown in Fig. 1 and the most influential one's were **Legal Issues and Security Issues.** Therefore an industry needs to initially start with work on the following two and afterwards proceed according to the digraph obtained by ISM for the successful implementation of Indsutry 4.0.

VII. CONCLUSION

The 20 Key Challenges to Industry 4.0 Initiatives for Supply Chain Sustainability identified in the above study are based on the latest trends in the industrial globe. These challenges play an important role in identifying the problems faced by large as well as medium scale enterprises w.r.t the implementation of latest developments related to Industry 4.0. With the help of Analytical Hierarchical Process (AHP) we are able to prioritise the challenges and find the most influential to the implementation of industry 4.0. And with the help of Interpretive Structure Modeling (ISM) we are able to identify the interdependence of the challenges upon each other and the priority of their elimination in the most effective way.

Fig 1: Digraph showing inter-relationship between the sub-criterion obtained using ISM technique



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