"ADOPTING INDUSTRY4.0 FOR RESILIENT AGRO-FOOD SUPPLY CHAIN: CHALLENGES AND IMPLEMENTATION FRAMEWORK"

A DISSERTATION

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DECLARATION

We, Ashish Aggarwal (2k17/ME/064), Jovial Sotra (2k17/ME/113) and Deepanshu Singh Seepal (2k17/ME/079) students of B.Tech (Mechanical engineering), hereby certify that the work which is presented in the Major Project entitled "Adopting Industry 4.0 for Resilient Argo-Food Supply Chain: Challenges and Implementation Framework" in fulfilment of the requirement for the award of the Degree of Bachelor of Technology in Mechanical Engineering and submitted to the Department of Mechanical Department, Delhi Technological University, Delhi is an authentic record of our own, under the supervision of Dr. Girish Kumar. The matter presented in this report has not been submitted by us for the award of any other degree of this or any other Institute/University.

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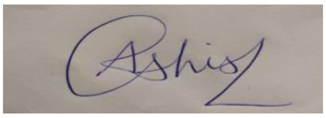

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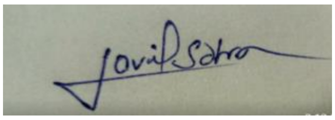

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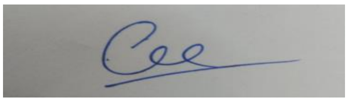

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To the best of my knowledge, the above work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere. I, further certify that the publication and indexing information given by the students is correct.

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DETAILS OF THE PAPER

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ABSTRACT

Purpose:-Benefits of Industry 4.0 can be described as improvement in the productivity, improvement in efficiency, collaborative working, increased knowledge sharing, agility and flexibility. . It helps us to gather real-time data from all parts of a process so that decisions can be made quickly and efficiently which reduces waste and hence, increasing productivity and overall equipment effectiveness. The application of Industry 4.0 in Indian agro food sector is in nascent stage. This sector has been playing a prominent role in the GDP and economic development of the country along with providing employment to a large population of India. Therefore, there is a need to study and analyze the challenges affecting the implementation of Industry 4.0 in Indian agro food sector.

Design-Comprehensive study of literature and help from experts have enabled us to find seven major challenges which are analyzed using BWM method in this study.

Findings- Findings revealed that Economic and Technical barriers which include **High initial financing cost, Lack of monetary funds, Digital privacy** are some of the major challenges to implementation of Industry 4.0 in agro food sector in India.

Implications- The results will help the researchers and practitioners in strategic decision-making for the improved application of Industry 4.0 in the Agro food sector.

Keywords: Industry 4.0, Challenges, Agro food sector, Best Worst Method, Sustainability

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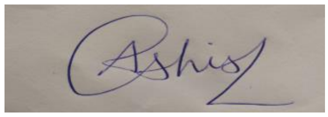

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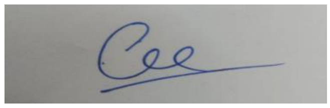

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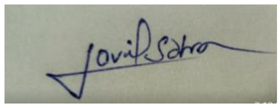

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SECTION 1: INTRODUCTION

1.1 Motivation

The agriculture sector has been playing an important role in overall development of country like India both in social aspect as well as economic aspect. Going by the figures we are able to see that this sector contributes to $1/6^{th}$ of the national income and has been providing employment to almost 50% of the current workforce in the country (Jana, 2020).It has been continuously fulfilling basic necessities like food, fuel, fiber and timber for increasing population of both humans and animals. Due to globalization, rapid demographic changes, evolving regulatory and legislative interventions it has become necessary that we start producing high quality, customized and value added products in the market. Countries like U.S.A ,Brazil, China have adopted technologies of Industry 4.0 in their agro food sector and have been producing outstanding results. Companies like John Deere have integrated sensors in their farming equipment and deployed big data applications that will help better manage their fleet (Rijmenam,2013).for large farms these technologies help in knowing tractor availability, service due dates, and fuel refill alerts. This helps in optimal usage of the resources and ensures the long-term health of farm equipment (Rijmenam, 2013).

The agro food sector which ranges from the primary agriculture area to the mature food and beverage sector is an integrated complex production chain. . It is considered as perhaps the biggest area worldwide with huge commitment to the monetary progression of countries and significant social effect. But the agro food sector is facing a number of that require a re-evaluation of current practices in production and trade, co-operation between enterprises along the vertical supply chain, the influence of governments on enterprises' management activities and environmental awareness.

Along with being active in digital innovation this sector has also been facing challenges in implementation of new technologies such challenges/barriers include infrastructural, skill gap barriers and many more. Industry 4.0 has been characterized as "a name for the current trend of automation and data exchange in manufacturing technologies, including cyber-physical systems, the Internet of things, distributed computing and cognitive computing and creating the smart factory(i-Scoop,2021). Industry 4.0 is a dream that developed from a drive to make the German assembling industry more cutthroat to an around the world embraced term. Its motivation is to change the business through "smart factories" that will permit greater flexibility in production needs, productive assignment of assets and integration of processes; from equipment monitoring to final delivery with the use of technologies such as integration of Cyber-Physical Systems (CPS), IoT and IOS, and the real time interaction between machinery, software and individuals (Patil and Shekhawat, 2019).

Technologies, such as Blockchain, Artificial Intelligence, Internet of Things, Big Data, Cloud Computing and Robotics have changed the way of farming around the world. These technologies are part of industry 4.0 and helped to improve current system into smart systems. There are many other technologies are being implemented or being prepared to implement. Some of few new technologies in the agro food sector include vertical and urban farming, precision farming, data driven farming, use of IoT sensors in field and on livestock, Big data, AI, etc. With the help of these Industry 4.0 technologies, a traditional agro food supply chain will be converted into a smart agro-food supply chain, and will be successful in meeting the upcoming production demand.

In developed countries like U.S.A technologies like precision agriculture has already been implemented and widely used there.in U.S.A alone the market of IoT farming is around 1.3 billion US dollar each year whereas countries like India, Malaysia, China, Brazil and others are still lagging behind in full implementation of these technologies. They have started to receive some PFS (Precision Farming System) methodologies, particularly on research ranches; however the adoption is still very limited. . In most non-industrial nations, paradoxically, there are no particular PFS programs because of an absence of capital, information and advancements (Salama, 2020).

In 2018, the World Government Summit published a report known as "Agriculture 4.0: The future of farming technology", which focused on development in agricultural with the help of these Industry 4.O technology.In India project like TKK (Tata Kisan Kendra), an initiative by Tata Chemicals Limited (TCL), has hoped to propel rural India from a traditional agro-food practices to a smarter age, using precision farming methods i.e. remote sensing to assess soils, pest invasion and crop health protection(Tata Chemicals Limited,2020). Government is likewise contributing by giving plans like Pradan Mantri Fasal Bima Yojana (PMFBY), which is presenting AI innovation for quicker settling claims for the ranchers. In any case, the fruitful execution is still far away possibility in the future.

The agro food area, nonetheless, faces numerous issues. The Indian agribusiness production network isn't serious on the world market. Various examinations report that at the farm gate level, the area is cutthroat. Nonetheless, when the produce arrives at the market, it isn't cutthroat. The significant test is that it requires technological standards to ensure the compatibility of equipment and also applicability of equipment in rural areas. The new challenge is the needed data exchange process with communication standards that partner with various frameworks together in a brought together system covering all parts of the agricultural sectors.

Beside from adopting modern technologies and engaging in capability development, Industry 4.0 also requires agro food supply chains to transform their business models and network structure, which will lead to change in the traditional relationships between suppliers, manufacturers, wholesalers, retailers and customers. There are already some industries such as electronics and fast-moving consumer goods (FMCG) adopting and moving along the supply chain 4.0; while other industries are still lagging behind. Seeing the diffusion rate of modern technologies in the agro-food industry ,which is lower than the anticipated value we can say that their implementation may involve challenges or lack of collaboration which we need to find out and overcome. The financial difficult spot of rancher prompts restricted speculation capacity in new production tools and restricted access to credits. The farmers in rural territory required extra interest in preparing with new advancements in agriculture 4.0. This emerged hole among conventional and smart farming. Appropriation of new strategies shows positive relationship with the effect of pay, net pay and farm profitability on adoption revealed a positive correlation. The adoption of industry 4.0 in farming area has a few difficulties. The agro-food sector of India has not created at standard with worldwide level. There are limited studies done on these topics. Hence, as a result, this study examines the challenges ahead of Indian agro food sector in adoption of industry 4.0 in it. The major objectives of the study are as follows:

- To identify the Challenges in adopting Industry 4.0 in agro food sector in India.
- To prioritize and to categorize the barriers into cause-and-effect groups.

In this study barriers are identified on the basis of literature review and expert discussions. Further, expert opinions are sought on importance of barriers in linguistic form. The data collected is used for further analysis using Best and Worst method to prioritize the barriers. The Best Worst Method (BWM) represents a powerful tool for multi-criteria decision-making and defining criteria weight coefficients. DEMATEL is employed to categorize the barriers in cause-and-effect category.

1.2 ORGANIZATION OF REPORT

The remaining organization of this paper is as follows; Section 2 identifies and describes various barriers and their sub barriers. Section 3 elaborates on the methodologies of BWM and DEMATEL. In Section 4 and 5, how the data has been collected and the implementation of BWM approach is shown for assessing the weight of barriers and developing relationship between them. Results are displayed in section 6 along with implications in section 7.Concluding remarks are given in section 8 .

SECTION 2: LITERATURE REVIEW

The following section comprises of the review of the Industry 4.0 concept, its implementation and the challenges encountered during its process of implementation.

2.1 Industry 4.0

This phrase was first referred to in 2011 as "*Industrie 4.0*", which can be abbreviated as I4.0 or just I4. Klaus Schwab, executive chairman of the World Economic Forum, has made the definition of the term to a wider audience through an article published by Foreign Affairs in 2015. This fourth era emphasizes innovations in communication and connectivity and emphasizes hardware-software systems that are combined with biology (cyber-physical systems).

The previous three revolution that led to industry 4.0 are briefly explained below:

First Industrial Revolution

With the First Industrial Revolution, humans changed from creating with their hands to machines using steam force and water power. The industrial revolution also affected the iron industry, the agribusiness, and material manufacturing, and mining despite the fact that it likewise had cultural impacts with an ever stronger middle class.

Second Industrial Revolution

The Second Industrial Revolution, also known as the Technological Revolution, occurred in the decades 1871 to 1914 as a result of the establishment of railways and transmission systems., which took into consideration quicker exchange of individuals and thoughts, as well as power. It was a time of incredible financial development, with an increase in productivity, which additionally caused a flood in joblessness since numerous assembly line **labourers** were supplanted by machines.

Third Industrial Revolution

The Third Industrial Revolution, otherwise called the Digital Revolution, happened in the late twentieth century, after the finish of the two world wars, coming about because of a log jam of industrialization and mechanical progression compared with past periods. The creation of the Z1 computer, which utilized binary floating-point numbers and Boolean logic, a decade later, was the start of further developed computerized improvements.

2.2 Industry 4.0 technologies

Big data:- One of the significant difficulties with information has been its quantum nature. An excess of information makes it hard to distinguish the applicable data and patterns that can prompt some clever examination. This is the place where "Big data" and analytics come in. They make it possible to recognize the exhibition of an individual part and its operating restrictions in order to prevent future production issues and make a deterrent move.

Cloud computing:- The business has seen a huge move in using cloud arrangements, and this will keep on developing. The cloud is being utilized for applications, for example, distant administrations, and execution benchmarking and its part in different business regions will keep on growing. With consistent progressions in innovation, machine information and usefulness will just keep on moving towards cloud arrangements. The cloud takes into consideration a lot quicker turn out of updates, execution models, and conveyance choices than independent frameworks.

Internet of things (IoT):- The IoT is a crucial convenience in Industry 4.0 driven courses of action. IoT is an arrangement of interrelated registering gadgets, mechanical and computerized machines, items and individuals that are furnished with remarkable identifiers and the capacity to move information over an organization without expecting human-to-human or human-to-PC cooperation.

For example smart watches in the market have transformed our wrists into cell phone by empowering text informing, calls, and the sky is the limit from there. With the best possible associations and information, the IoT can tackle gridlock issues, lessen clamor and contamination.

Simulation:- The simulations of systems allow assessment of various scenarios. When the situations are evaluated, practical arrangements can be created, tried and actualize a lot faster prompting diminished expense and time to showcase.

Autonomous robots: - They are utilized to robotize creation techniques over the different areas and are controlled by the idea of Internet of Things (IoT). This interfaces gadgets and PC machines to speak with one another. Materials can be shipped across the manufacturing plant floor by means of autonomous mobile robots (AMRs), staying away from obstructions, planning with fleet mates, and recognizing where pickups and drop offs are required in real-time by associating with a focal worker or information base, the activities of robots can be composed and mechanized to a more noteworthy degree than at any other time. They can complete endeavours insightfully, with irrelevant human data.

Augmented reality (AR) :- Through the use of augmented reality, humans can better integrate and interact with electronic systems by providing real-time information in an effective manner.

Cyber security:- The security of data gets principal as we move away from shut frameworks towards expanded network from the IoT and cloud. Security and unwavering quality empower the productive utilization of a really current and digitized creation work measure, using the total of the benefits of an associated climate.

System Integration:- Generally systems are exceptionally mechanized inside their own operations and battle to communicate with different systems. Principles and open engineering support the simple exchange of data both to the business and to the client/end client.

Additive manufacturing:- This keeps on getting progressively significant for small-batch applications or for the creation of individual parts or customized items. This will be used either really with the customer or by suppliers to improve plans with extended execution, versatility, and cost ampleness.

2.3 Barriers in the adoption of I4.0 in the Indian Agri-food section

The adoption of I4.0 provides access to a multitude of dimensions of advancement to any country of the world. However, its adoption is in the nascent stage. Multiple barriers are being faced in the adoption of Industry 4.0 in India, which are identified by a detailed literature review. The below-mentioned categories and sub-categories of barriers play a vital role in the adoption of I4.0 in India. There are seven main categories of barrier identified which are: Technical barrier (TB), Legal barrier (LB), Infrastructure barrier (IB), Skill gap barrier (SgB), Economic barrier (EB), Market barrier (MB), and Policy barrier (PB). A brief description is given here:

2.3.1 Technical Barrier

The barrier faced in the implementation of technology caused due to the reliability of technology, and the quality standard of hardware. This causes reluctance to pay from stakeholders, investors, and industries. There are few sub-categories under the technical barrier which will explain this in detail.

Performance and Reliability of Cyber-physical system:

Cyber-physical system acts as an interface whose purpose is to manage and maintain the workload in real-time. The failure of this system can lead to loss of money, property, and human life (Koc et al., 2019). Having reliable IoT sensors for operations and detecting fault in cyber physical system (Kossakowska et al., 2019).

IoT quality:

With the lack of standard operating procedure, designs, and hardware in IoT for manufacturers and developers, can produce low-quality devices for the customer-end. Poor resource-constrained IoT devices will create concern toward the reliability and security in an IoT environment (Clarke et al., 2017).

Digital privacy:

I 4.0 promise a connected and smart cyber-physical manufacturing system dealing more with information. D2D and M2M communications often create data and flow of data all over the system. Privacy is not just the security of data but also protection against cyber threats and also cyber warfare with the war over control of data, with data as the upcoming commodity. The way to securing personal user data is to differentiate dealing with security and privacy (Yang et al., 2019).

Wireless data network:

The introduction of 5G in India’s telecom services is a major step to ease up the issue regarding high speed and consistent internet connectivity, which would help in developing an industry 4.0 supporting and digital India.

2.3.2 Legal barrier

The challenges faced in procuring the digital industry to abide by the law, especially the existence of law in a cyber-physical system and the role it should play in the aspects of human civilization. There is a barrier mentioned below that put concern on the legitimacy of a cyber-physical world.

User data concern over the third party:

With concern being the privacy of the user and the possibility of data access by the third party to party uninvolved with the user, due to technical fault, unacknowledged permission granted by the user or 3rd party data breach, can causes concern over the legitimacy of agencies. Safe guarding consumer privacy and proper compensation regarding privacy threat in an e-commerce should be validated (Fernando et al., 2019).

2.3.3 Infrastructure barrier

Some aspects of I4.0 technology requires necessary infrastructures that provide a base for the foundation and development of this industry. Some of the infrastructure barriers in the adoption of I4.0 are mentioned below in detail.

ICT Infrastructure:

One of the challenges of I4.0 for our nation is not only the self-automated individual machines but the need for a whole cyber-physical system, which will diagnose, configure and optimize on its own, with the key requirement being the wireless communication network. Proper ICT resources lead to economic growth transition (Malik et al., 2018).

Cyber Security Infrastructure:

With I4.0 upgrades, upcoming changes to the ICT sector will bring more vulnerability to data security on a national scale and a preconditioned requirement for trusted cyber security (Chaturvedi et al., 2009). Therefore, an infrastructure that not only connects and create a hub for data but also provide data protection against cyber threats.

Smart factory:

Smart factories loaded with big data, IOT, cloud computing, AI, and additive manufacturing, creating a factory that can think, perform tasks, and trouble shoot issues all on its own will be a huge step for Indian industry (Vaskenly et al., 2018).

Research and development:

There is a need for continuous research on the challenges to be faced in the implementation of I4.0, its technology, and the changes it is going to bring to India. Many jobs have been lost due to IT and automation, especially for the economically weaker section of India (Vaskenly et al.,2018). A cybersecurity breach can bring user data privacy issues and bring negative losses to the business franchise (Corallo et al., 2020).

2.3.4 Skill gap barrier

There is a set of skills required to qualify and engage with I4.0 adopted industries, more oriented toward a cyber-physical interaction, rather than hard-earned labour work which employs more than 50% of an Indian worker. There are a few skill gap barriers mentioned below in detail.

Lack of leadership:

Indian business industry faces a lack of a leader, with a strong vision toward adoption of I 4.0 in the Indian market, which could hinder widespread adoption. There have been few collaborations between Indian companies to develop new IoT and M2M solutions (Poklemba et al., 2018).

Lack of qualified worker:

India lacks manpower and personnel with much-needed skills requirements relates to automation, programming, data and analytics, Artificial Intelligence, system integration, and software development, to create an I4.0 powered manufacturing system. The government, industry, and academic institutions should take the step to create I4.0 qualified workers (Rauch et al.,2018).

2.3.5 Economic barrier

The economic favours toward changes is a vital factor in adopting technology trends. Some of the main economic barriers to be faced in India, are mentioned below in detail.

High initial financing cost:

There is a high initial cost for development on infrastructure and technology, with an unknown return on investment and additional financial need for issues in the new manufacturing system (Phuyal et al., 2020). There is also hesitation from stakeholders and investors to the upcoming changes.

Lack of monetary funds:

One of the primary concerns regarding any project is access to monetary funds from stakeholders, investors to invest over on a project with unknown capability and suitability with a nation (Towner et al., 2020).

Rise of Unemployment:

Agricultural industry employing 60% of India population (Statista,2020), which interprets lack of personnel who can adapt to I4.0 changes, also interprets the rise of unemployment for the rural farmer and other economically weaker section with the restricted skill set, in an automated industry (Dhanya M. et al., 2018).

2.3.6 Market Barrier

The adoption of I4.0 will produce major changes in the market trends and culture, affecting the relationship of supplier and consumers, to the need of understanding how these changes will profit not only major corporations but to the major weaker-sections of the society. There are a few mentioned below in detail.

Farmer Perception:

Farmer circumstances point of view, toward the assessment of technology need and its suitability for them, should be of aware. To increase the probability of adoption of technology, the government should invest in farmer training and awareness build-up (Waithaka et al.,2004).

Internal cultural transformation:

There is a lack of digital culture, with upcoming I4.0 enterprise are focusing on empowering their people and creating an entrepreneurial mindset, to drive their people to become leaders to develop flexible adaptive quick decision making and developing sense to assess risk in an era of automation, AI and robotics (Majid Ziaei Nafchi , Hana Mohelská., 2020).

2.3.7 Policy barrier

The role of government in creating a policy framework, not only helps in the widespread promotion of the technology but also provides legitimacy to the upcoming trends which could result in better adoption. Some of the policy barriers the Indian government could face are mentioned below.

Government role in the collaboration between independent agency and farmers:

The government should form a diplomatic relationship with farmers regarding agricultural policies, assuring with legitimate independent agency and awareness toward government true motive, and develop knowledge growth among rural farmers, about upcoming agricultural revolution. Independent agencies need to rely on legitimacy to integrate their innovation in government (Monk et al., 2020).

Barriers	**Symbol**	**Sub-Barriers**
Technical barriers (TB)	TB1	Reliability of Cyber-physical system
	TB2	IoT quality
	TB3	Digital privacy
	TB4	Wireless data network
Legal barriers (LB)	LB1	User data concern over third party
Infrastructure barriers (IB)	IB1	ICT Infrastructure
	IB2	Cyber Security Infrastructure
	IB3	Smart factory
	IB4	Research and development
Skill gap barriers (SgB)	SgB1	Lack of leadership
	SgB2	Lack of qualified worker
Economic barriers (EB)	EB1	High initial financing cost
	EB2	Lack of monetary funds
	EB3	Rise of Unemployment
Market barriers(MB)	MB1	Farmer Perception
	MB2	Internal cultural transformation
Policy Barriers	PB1	Government role in collaboration between independent agency and farmers

SECTION 3 METHODOLGY

For the introduction of industry 4.0 practices in Agro food sector in India along with cutting the risks and challenges that we are going to face in its introduction, prioritization of the barriers is the first step that we must take to overcome these challenges. Prioritization of these barriers will lead us to work in an efficient and faster way to bring the change in the Agri food sector in India in introducing Industry 4.0. Prioritization of the barriers is important because it enables us to keep a clear image of the path to achieve our goal, challenges that need the prime focus of all the challenges can easily be found by doing the prioritization of the barriers. We should understand the role that each of us hold for solving the prominent issues in the implementation of the industry 4.0 in Agri food sector. India is a developing country and an agrarian economy, hence bringing the transformation in this field will help the farmers, common people, and our great nation. India is an emerging economy hence prioritization of the barriers itself become a major task. Proper prioritization is needed to be done of the barriers to bring the change in. Barrier prioritization is a multi-criteria concept, hence to understand the significance of every criterion, multi-criteria decision-making method should be used. By studying past researches, we have found that there are various available methods to prioritize the barriers like best worst method (BWM), analytic hierarchy process (AHP), analytic network process (ANP), DEMATEL etc.

3.1 BWM (Best Worst Method)

BWM is an analogical method for pairing, that supplies a structured way to compare. Best worst method assesses a set of options in relation to a set of critical criteria. The BWM decision is based on a systematic pairing criterion. Namely, after the decision maker (DM) names the decision criteria, the DM selects two criteria: the best criterion and the worst criterion. The best criterion plays a particularly key role in decision making while the worst criterion holds an opposite role. The DM then lays choices on the best standard over other criterions and choices on the worst standard using values from a pre-defined range (e.g., 1 to 9). Inputs for the optimization is taken from these two sets of associated comparisons, whose outcome is the weights of standards.

Key feature of BWM is, it uses a structured method to create paired analogies that give decent result. This method is previously applied in various fields such as in agriculture, airlines, industries, and many more real-world problems. Their applications such as, assessing the quality of aviation baggage handling systems using SERVQUAL and BWM. In this research the SERVQUAL model is proposed to assess the service quality of luggage handling systems. The best worst method (BWM) is used to calculate the weight of a standard. BWM data is collected through a sample of travelers from different countries. (Jafar Rezaei and Oshan Kothadiya, et.al, June 2018), the supplier-selection life cycle approach that relates environmental and traditional standards using the best worst method (Jafar Rezaei and Lori Tavasszy et.al, November 2016), using Best Worst Method in checking the social sustainability of supply chains (Hadi Badri Ahmadi and Jafar Rezaei et.al, November 2017), evaluation of external forces affecting the stability of the oil and gas supply chain using the best-worst method (Wan Nurul Karimah Wan Ahmad and Saman Sadaghiani et.al, March 2017), Measuring the relative importance of the logistics performance index indicators using Best Worst Method (Jafar Rezaei∗, Wilco S. van Roekel, Lori Tavasszy, 2018). The target is to find the best weights then deducing the consistency ratio through optimization model set up using the comparison system. There are five steps involved in this method (Rezaei, 2015).

Step 1. Determine and create a list of decision criteria.

Criteria (X_1, X_2, X_N) must be found to come to a decision.

In reference to these parameters, the output of the alternatives is calculated.

Step 2. Determine the best and worse criterion to use in the decision-making situation.

The best criteria are those that are the most preferred, proper or significant.

In contrast, it is less desirable, less preferred, or less significant.

Here only the criterion is considered and not the value of the criterion.

Step 3. Decide the preference for the right criterion over all other parameters

This value is represented by a number between 1 and 9. The resulting Best-to-Other's vector would be:

$$Y_p = (y_{p1}, y_{p2}, \ldots, y_{pn}),$$

where, y_{pk} indicates the highest criterion P's choice over criterion k.

Step 4. Determine how far one of the other parameters prefers the worse criterion.

In this case, too, a number between 1 and 9 is assigned. The Others-to-Worst scale will be as follows:

$Y_w = (y_{1w}, y_{2w}, \ldots, y_{nw})^T$,

The parameters k are preferred over the worst criteria w is y_{kw}

Step 5. Decide and list the best weights.

The maximum absolute differences $\{| w_p - y_{pk}w_k |, |wk - y_{kw}w_w|\}$ for all k should be reduced when deciding on the best weights for the parameters

This can be formulated as follows (Rezaei,2015):

max $\min_k \{| w_p - y_{pk}w_k |, |w_k - y_{kw}w_w|\}$

$\Sigma_k w_{k =}$ 1(a)

$w_k \geq 0$, for all k.

Now, in equation a,

min ξ^z

subject to

$| w_p - y_{pk}w_k | \leq \xi^z$, for all k

$|wk - y_{kw}w_w| \leq \xi^z$, for all k

$\Sigma_k w_{k =}$ 1(b)

$w_k \geq 0$, for all k.

After solving the problem Eq. (b), the appropriate weights are measured (w_1 *, w_2 *, w_3 *…, wn *) and ξz *. ξz * be a direct indicator of the compatibility of the comparison system. When the approximate value of ξz * approaches zero, the fluctuations increase, and, as a result, the comparison is more reliable.

3.2 DEMATEL

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) is another MCDM method for devising and scrutinizing a structural model involving random connections between complex factors. The DEMATEL is digraphs-based method, in which involved factors are severed into cause groups and effect groups. Instead of using drifting graphs, digraphs are more useful and convienent. Among the elements of the system, a contextual affinity is displayed by the digraphs, where the digit represents the influence strength. Digraphs are also useful to demonstrate the directed relation-ships of subsystems.

Previously numerous research works had been done in various fields using the DEMATEL approach. Fuzzy Dematel method was applied for developing global managers' competencies (Wu, W.-W., & Lee, Y.-T. et.al 2007). DEMATEL method was used for finding key success factors of hospital service quality (Shieh, J.-I. et.al 2010). DEMATEL was applied for investment projects portfolio prioritization, agri-food supply chains for sustainable initiatives, and cloud adoption determinants analysis (Hidayanto et al. 2015; Altuntas and Dereli 2015; Mangla et al. 2018). DEMATEL method was used in evaluating performance criteria of Employment Service Outreach Program personnel (Wu, H.-H., Chen, et.al. 2010).

Steps used in DEMATEL method are given as (Hsuan-Shih Lee. Et.al 2013): -

Step 1: Collection of data recieved from questionnaires, filled by experts and reaching an average matrix S for evaluation.

Let us consider 'G' experts and 'h' factors,

Experts are asked to rate the extent to which they believe factor o influences factor p.

t_{op}^{n} is a pairwise relation between the o^{th} factor and the p^{th} factor given by the n^{th} expert.

No impact, low influence, medium influence, high influence, and extraordinarily high influence are represented by the integer scores 0, 1, 2, 3, and 4. Each expert's scores will be combined to form a z×z non-negative response matrix $T^n = [\ t_{op}^{n}]_{z\times z}$ is obtained where $1 \leq n \leq G$. Therefore $T^1, T^2, T^3,.. T^n$ are the G experts' response matrices. The z×z average matrix S for all experts can then be computed by combining the G experts' scores as follows:

$$s_{op} = \frac{1}{G}\sum_{n=1}^{G} t_{op}^{n}$$

Here, each solution matrix T^n has all its diagonal elements set to zero, implying that no control is provided by itself. The original direct relation matrix is also defined as the average matrix

S= $[s_{op}]_{z\times z}$.

The matrix S depicts the original direct impact that a factor has on other factors as well as the effects that other factors have on it. Drawing an impact diagram may also be used to map out the causal effect between each pair of variables in a scheme.

Step 2: Calculate the original normalized direct-relation matrix U.

U= $[u_{op}]_{z\times z}$. is the normalized original direct-relation matrix obtained by normalizing the average matrix S as follows:

$$\text{Let } e = \max\left(\max_{1\le o\le z} \textstyle\sum_{p=1}^{z} s_{op} \;\middle|\; \max_{1\le p\le z} \sum_{o=1}^{z} s_{op}\right)$$

Then U = S/e

Since the overall direct impact that the factor o has on other factors is represented by the sum of each row o of the matrix S, $\sum_{p=1}^{z} s_{op}$,
$\max\limits_{1\le o\le z} \sum_{p=1}^{z} s_{op}$ represents the highest total direct effect of all factors.
The highest cumulative direct impact earned for both causes is $\max\limits_{1\le p\le z} \sum_{o=1}^{z} s_{op}$. Similarly, since the overall direct effect obtained by the factor p is represented by the sum of each column p of the matrix S, $\sum_{o=1}^{z} s_{op}$

Step 3: Assess the total relation matrix.

By adding U, U^2, U^3....U^∞ together, we will get the total control or total relationship. The original DEMATEL assumes that U^k can converge to a zero matrix, and that $V = U + U^1 + U^2 +\ldots + U^\infty$ can be obtained by

$$V = \lim_{z\to\infty}(U + U^2 + \ldots + U^k) = U(I - U)^{-1}$$

After obtaining $V = [v_{op}]_{z\times z}$, we can define a and b as z×1 vector standing for the complete relation matrix V sum of rows and number of columns, respectively

$$a = [a_{op}]_{z\times 1} = \left(\sum_{p=1}^{z} v_{op}\right)_{z\times 1}$$

$$b = [b_{op}]'_{1\times z} = \left(\sum_{o=1}^{z} v_{op}\right)'_{1\times z}$$

The superscript ` stands for transpose.

Step 4: Determine the effect by setting a threshold value. -map-of-relationships

It is important to set a threshold value c to filter out any negligible effect in the matrix V to understand the structural relationship among the variables while holding the complexity of the structure to a manageable level. Although each factor of the matrix V supplies insight about how one factor influences another, the decision-maker must set a threshold value to minimize the uncertainty of the matrix V-implied structural relation model.

Only those variables whose influence in the matrix V exceeds the threshold value should be selected and shown in an impact-relations-map (IRM)

3.3 **Data Collection**

This assessment utilizes overview strategy to assemble data from different experts by distributing a review among the supply chain experts working in agro food area.

Experts evaluated the starter draft of the survey and commented on the understandability, subject and portrayal of the audit review. Thoughts were joined and improvements in the review were done before appropriating for data combination.

Specialists were chosen from industry, academia and not for profit organizations to mirror their insight and involvement with the result of the examination and give better answers for its execution. It was guaranteed that the specialists had exhaustive information on the topic. The qualities of the interviewees are appeared in Table:

EXPERT	BACKGROUND	FUNCTION	EXPERTISE
EXPERT 1	AGRO FOOD INDUSTRY	Agribusiness Professional	Agribusiness Consulting, Researcher
EXPERT 2	AGRO FOOD INDUSTRY	Teacher	Supply chain, Quality management
EXPERT 3	AGRO FOOD INDUSTRY	Consultant	Food Security
EXPERT 4	AGRICULTURE INDUSTRY	Farmer	Farming

Table 4.1: Expert data

3.4 Implementation of BWM

In this section, the BWM methodology described in the previous section is implemented for assessment of the weight of barriers and establishing their relationships. The barriers in implementation of Industry 4.0 in agro food sector in India were identified on basis of literature review and interactions with domain experts.

After reading the barriers in the questionnaire and thinking about them the experts are proceeded to second step . Second step consists of selecting a best and a worst criteria out of all.

After the best and worst method are selected by the experts ,they give rating once as per best criteria to all and once for worst criteria using a numerical value between 1 to 9 as shown in the table below. The mathematical data which is obtained from the questionnaire was examined through the BWM technique. The outcomes of this multi decision technique i.e. BWM calculations are the optimal weights of the different factors and sub factors based on

Table 5.1: Relative values for best criteria through expert opinions

EXPERT NO	BEST TO OTHER / BEST CRITERIA	EB	TB	IB	SgB	MB	PB	LB
EXPERT 1	EB	1	3	7	3	8	4	9
EXPERT 2	TB	1	1	9	2	9	4	3
EXPERT 3	EB	1	4	6	3	7	3	8
EXPERT 4	TB	2	1	8	2	9	5	3

Table 5.2 : Relative values for worst criteria through expert opinions

OTHER TO WORST	WORST CRITERIA			
	Expert 1	**Expert 2**	**Expert 3**	**Expert 4**
	LB	LB	SgB	SgB
EB	5	4	5	4
TB	4	4	6	5
IB	8	7	9	8
SgB	6	6	1	1
MB	3	2	4	3
PB	2	3	3	5
LB	1	1	9	8

After this process, local and global weights (W1*, W2*,............,Wn*) and consistency ratio are calculated. Consistency ratio is a direct indicator value, which shows the relative consistency of the comparisons of different factors that are made. On the off chance that consistency proportion esteem is near zero it implies the dependability is extremely high.

The relative ranking of all barriers/challenges on the basis of average weight is shown in Table. Complete consistency is calculated.

Expert No.	Relative Weight							Consistency ratio
	EB	TB	IB	MB	PB	LB	SgB	
1	0.343932	0.175549	0.075235	0.065831	0.131661	0.032244	0.175549	0.182713838
2	0.307502	0.252945	0.047117	0.047117	0.106014	0.027278	0.212027	0.171109733
3	0.365282	0.207322	0.088852	0.077746	0.155492	0.069107	0.036199	0.256684492
4	0.320178	0.246804	0.046693	0.046693	0.105058	0.210117	0.024458	0.173429683

Table 5.4: Avg. Weights and ranking of Barriers

Table 5.3: Relative weights and consistency ratio

BARRIERS	Avg. Weight of Barriers	Relative Rank
EB	0.334223	1
TB	0.220655	2
IB	0.064474	6
SgB	0.059347	7
MB	0.124556	3
PB	0.084687	5
LB	0.112058	4

SECTION 4: RESULTS AND DISCUSSION

Our research examined the challenges that will arise in the implementation of Industry 4.0 in agriculture, including the severity of the challenges, as well as the implications of the challenges.. The BWM approach is used to evaluate the relative weightage of the challenges and we finally found out the seven barriers that are going to be faced while implementation. Seven significant challenges to the implementation of industry 4.0 in the Indian agro-food sector were selected through literature survey and expert responses obtained from survey questionnaire. Factor and sub factors were identified on the basis of expert discussion. They are classified into as described below:

(1) Technical Barrier (TB), (2) Legal Barrier (LB), (3) Infrastructure Barrier (IB), (4) Skill gap Barrier (SgB), (5) Economic Barrier (EB), (6) Market Barrier (MB), (7) Policy Barrier (PB).

In our research, we found out that the 'Economic barrier' carried the highest weightage with 33.4% , therefore, demanded to be the most important barrier to look upon, based on BWM approach. It is followed by 'Technical barrier' with 22.06% weightage, 'Policy barrier' with 12.45% weightage, 'Skill Gap barrier' with 11.2% weightage, 'Legal barrier' with 8.4% weightage, 'Infrastructure barrier' with 6.4% weightage, and 'Market barrier' with 5.9% weightage

SECTION 5: CONCLUSION AND FUTURE SCOPE

5.1 Implications

Seven significant hindrances were distinguished and focused in terms of the value of the context of developing countries. These difficulties will fundamentally affect future exploration led on embracing industry 4.0 in agro food area. The discoveries of this examination will assist analysts with planning an applied system for smooth change towards new advancements in agro food industry in arising economies.

The examination is led with regards to the Indians as it is an agricultural nation with huge population to take care of and as seventh biggest nation on earth. Given such high population development and restricted admittance to assets, lessons related to the challenges and solutions for creating a can help emerging countries to make resilient agro-food supply chain.

Examination discoveries can be helpful for those associations that are making arrangements for agro food chains to work well orderly and significantly quicker. Discoveries can assist an association with understanding the greatness of each challenge. The causal connection between the boundaries in execution of industry 4.0 in agro food area will help in working all the more effectively. Continuing the standardization of these barriers can help startup companies like AgriBazaar, Crofarm and **Pebble Labs** to implement their action and address key challenges that could significantly affect its implementation. Later on, the discoveries may help organizations and government comprehends the need to embrace strategies and beat these boundaries in agro food store network and see the advantages that can be acquired from them.

5.2 Conclusion

Adoption of Industry 4.0 for resilient agro-food supply chain requires utmost attention, thorough planning, and resource management with efficacy. During the implementation of Industry 4.0 in agro-food supply chain in India, the several barriers that we are going to observe can be identified as Technical Barrier (TB), Market Barrier (MB), Economic Barrier (EB), Policy Barrier (PB), Infrastructure Barrier (IB), Legal barrier (LB), and Skill gap barrier (SgB).

Our approach using BWM methodology helped us in figuring out among the barriers, the most significant ones. Using this research data, we can create streamlined models and different plausible ways to adopt the Industry 4.0 in India, by removing the significant barriers.

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