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Identification of Barriers to the Implementation of IoT in the Indian Agriculture Sector

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Abstract

With an increasing population and declining workforce in agriculture, the Indian agriculture sector is facing a downfall in terms of productivity. To increase the declining productivity, an adaptation of automation technologies i.e., Internet of Things (IoT), cloud computing, etc. is a must. In recent times IoT has made its impact on every major industry. The global agriculture sector is already incorporating smart methods to improve productivity, reduce waste, and control the overall management of farming related tasks. But India is far behind in the nationwide implementation of these smart technologies, this is due to the presence of various challenges. The goal of this study was to identify those implementation barriers and establish contextual relationships among them. In this study, barriers were identified through literature reviews and expert opinion and the methodology selected for this is a combined ISM-DEMATEL approach.

Keywords

Internet of Things, Agriculture, Smart farming, Barriers, ISM, DEMATEL

Introduction

A wide range of industries, including manufacturing, aviation, and agriculture, are paying close attention to the IoT, which is seen as one of the most significant areas of future technology [1]. The IoT is a network of physical objects that are linked together via the internet in order to exchange and collect data. The application of IoT offers efficient and reliable solutions to several domains like smart city, smart home, healthcare sector, supply chain, logistics, smart agriculture, etc. [2]. One of the major advantages of IoT implementation is that it controls and continuously monitors operations with zero or minimal human intervention while facilitating user specific applications.

The backbone of India's economy is agriculture, which contributes between 65 to 70% of the country's GDP. It generates 17% of GDP from 60.3% of agricultural land [3]. Agriculture supports 60% of people's jobs. However, the high percentage of rural communities living in poverty is mostly due to the strong reliance on agriculture for subsistence (more than 50% of the population) [4]. The agriculture industry is dealing with a number of issues, such as the shrinking size of small farms and the migration of farm labour caused by growing urbanisation (estimated to drop to approximately 26% of the labour force by 2050, future water scarcity crisis, etc.). The Ministry of Agriculture's studies indicate a connection between farm mechanisation and increased output. Increased savings on agricultural inputs like seeds, fertiliser, etc. will result from this [5].

Although IoT proves beneficial to the agriculture sector there are some challenges being faced during implementing these technologies, so addressing those barriers is important. The major goal of this study was to first identify the barriers preventing IoT deployment in the agriculture sector, then identify some of the most important ones by using the ISM-DEMATEL approach, and finally acquire a structural framework for barriers. The rest of the article is organised as follows: Section 2 reviews the related and recent literatures. Brief introduction of methodology using ISM and DEMATEL has been discussed in section 3. Section 4 describes the ISM Model and cause effect diagram and results obtained using the above approach. Section 5 concludes the research by providing a conclusion and suggestions for further investigation.

Literature Review

The IoT can be thought of as a global network that enables communication between people, things, and other things [6]. The term "Things" refers to electronic devices and sensors.

IoT offers a diverse set of tools to counter various challenges faced by the farmer in traditional farming, in a way it is helping reshape the agriculture sector. To monitor the farm wireless camera, wireless sensor networks are used with the interface of smartphones (or other smart devices), to which they can connect from anywhere at any time. To manage farming processes such as irrigation, nutrient management, etc. are regulated through dedicated sensors and actuators [7]. There are still significant difficulties and constraints in IoT-based agricultural systems, even though they offer useful information on farm-related physical factors that may be used to enhance conventional cultivation methods and overall productivity. The biggest obstacles to implementing smart agriculture applications are those related to the physical world, the market, and IoT applications in general [8].

IoT in the Indian agriculture sector: In India, more than 50% of the population is highly dependent on agriculture which predominantly consists of small farmers. According to the 2010-11 agriculture Census, almost 85% of farmers are in marginal and small farm categories and have less than 2 hectares of farmland. These small farms, though operating only on 44% of land under cultivation, are the main providers of food and nutritional security to the nation, but have limited access to technology, inputs, credit, capital, and markets [3]. The farmlands are also experiencing challenges such as climate change, degrading land resources and quality, water scarcity, pests, diseases, etc. In such alarming conditions implementing current automation technologies in the agriculture sector would be the right step to take. Though India has started adopting these technologies at a very slow pace, that is why barriers, which are slowing down the adoption rate, need to be addressed.

Barrier identification: To identify the barriers in the implementation of IoT in the Indian agriculture sector, literature searches, published interviews of industry experts, and industry reports have been used. The main method used to identify the barriers in this paper was to mobilize various forms of literature reviews. For the period between 2011 and 2022, take into account the following electronic databases: Elsevier (Science direct), Emerald Insight, Scopus, and Springer. These databases contain scientific publications, journals, articles, reports from the government, and business reports from firms. For the study and development of the framework indicated in this part, ten barriers have been identified and were as follows:

1. **Interoperability (B1):** Achieving technical, syntactic, semantic, and organizational interoperability is challenging. It is necessary to achieve this so that systems and people can work together seamlessly [6, 9].
2. **IoT privacy and security (B2):** Different layers of IoT are vulnerable to potential attacks such as Denial of Service (DoS), data theft, device capture attack, SQL injection attack, etc. [10, 11].
3. **Cost (B3):** Consisting of setup and running costs, the cost of implementing IoT technologies is usually high [2].
4. **Lack of awareness and knowledge (B4):** For farmers in rural areas, the farmer's failure to use knowledge for utilizing beneficial government schemes and advanced technologies in their favor, can be a serious obstacle [7].
5. **Infrastructure (B5):** Supporting infrastructures required for IoT adoption in the Indian agriculture sector are far from ready. Internet connectivity and electricity supply seem to be major challenges for IoT adoption [12].
6. **Scalability (B6):** Scalability is associated with the handling of a continuously increasing number of IoT devices [13].
7. **Regulatory challenges and government policies (B7):** Regulatory policies and government policies are necessary to protect farmers' rights and support them in utilizing these technologies [6].
8. **Networking challenges (B8):** Limited battery capacity, communication range, propagation losses due to open agricultural surroundings, etc. majorly influence affects the implementation of IoT [14].
9. **Choice of technology (B9):** IoT technologies are still in the immature phase, it is challenging to choose the right technologies while considering the scale of farms, cost-related factors, geographical locations, etc. [12].
10. **Reliability (B10):** The IoT devices (sensors) are supposed to be installed in harsh outdoor conditions which makes them vulnerable to extreme conditions [7].

Methodology

The primary goal of the study was to create a structural framework for barriers, in which an integrated ISM-DEMATEL approach will be utilized. It starts with the identification of barriers based on pre-existing literature then data related to the pair-wise relationship among barriers, was collected. Based on this data ISM and DEMATEL analysis was done in order to obtain the ISM model and cause/effect relationship.

ISM: It is easier to understand and build a structural model based on the expert's judgement when a complicated structure is broken down into visible and well-defined structures using the ISM, a qualitative technique [15]. ISM methodology follows the following steps:

Step 1: It begins with the identification of obstacles based on literature analysis.

Step 2: A pairwise comparison is made between barriers in order to establish contextual relationships among barriers.

Step 3: To indicate the pairwise relationship among variables formation of Structural Self-Interaction Matrix (SSIM). The matrix is represented in the form of V, A, O, and X. As these symbols were to find the relation between the factors "i" and "j", where, V means forward relation, i reaches to j, A means Backward relation, j reaches to I, X means Relation in both directions, and both i and j affect each other, and O means no relation. Based on the steps described above, the matrix has been developed as given in table 2.

Table 1: Barriers.

Barriers Code	Barriers	References
B1	Interoperability	[6, 9]
B2	IoT privacy and security	[10, 11]
B3	Cost	[2]
B4	Lack of awareness and knowledge	[7]
B5	Infrastructure	[12]
B6	Scalability	[13]
B7	Regulatory challenges and government policies	[6]
B8	Networking challenges	[14]
B9	Choice of technology	[12]
B10	Reliability	[7]

Step 4: The Reachability Matrix was developed based on SSIM by replacing V, A, X, and O based on the following rules:

1. If cell (i,j) in SSI Matrix is "V" then cell (i,j) is substituted by 1, and (j,i) is substituted by 0.
2. If cell (i,j) in SSI Matrix is "A" then cell (i,j) is substituted by 0, and (j,i) is substituted by 1.
3. If cell (i,j) in SSI Matrix is "X" then cell (i,j) is substituted by 1, and (j,i) is substituted by 1.
4. If cell (i,j) in SSI Matrix is "O" then cell (i,j) is substituted by 0, and (j,i) is substituted by 0.

Based on the rules mentioned above SSIM matrix was converted to reachability matrix.

Step 5: After taking into account the transitivity rule, which stipulates that if factor X influences factor Y and factor Y affects factor Z, then factor X will also affect factor Z, the final Reachability Matrix was obtained.

Step 6: The final Reachability Matrix was divided into levels according to its levelling.

Step 7: A digraph was drawn after level partitioning, and transitivity linkages were taken out. A final digraph was created when the indirect links were removed. The digraph was then transformed into an ISM model as a result of this process. Then, utilizing MICMAC, elements can be further divided into four clusters based on the driving power and dependence power.

Step 8: Look for conceptual consistency issues.

DEMATEL: The DEMATEL method simplifies complicated problem structures and determines criteria that need more attention. The steps required for the DEMATEL method were given as follows:

Step 1: After the identification of dimensions, a pairwise comparison of criteria was done in order to obtain a direct relationship among barriers. Pair comparison was made based on the expert opinion of 3 academic experts with minimum qualification as Ph.D. with more than 5 years of experience in the area of industrial engineering and 4 industrial experts working as senior managers in reputed industries.

Step 2: To indicate pairwise relationships among dimensions, a Direct Relationship Matrix (DRM), Z was established with help of a five-point linguistic scale. As shown in table 3.

Step 3: A Normalize Matrix (NM), Y was developed from a DRM.

Step 4: The final Total Relation Matrix (TRM), T was created.

Step 5: After the Total Relation Matrix, an Influential Relation Map (IRM) was created to find the cause-and-effect dimensions. For this, if (Ri-Ci) value for any criteria was negative, that dimension will be considered as "effect" and if it's positive then it was considered as "cause".

Table 2: SSIM matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Interoperability (B1)		V	V	A	O	A	O	O	A	V
IoT privacy and security (B2)			X	A	O	A	A	A	A	V
Cost (B3)				O	O	O	A	V	V	A
Lack of awareness and knowledge (B4)					V	O	V	O	O	O
Infrastructure (B5)						V	A	V	V	V
Scalability (B6)							O	O	A	O
Regulatory challenges and government policies (B7)								O	O	O
Networking challenges (B8)									A	V
Choice of technology (B9)										V
Reliability (B10)										

Table 3: Direct relationship matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0	1	1	0	0	2	0	0	0	0
B2	2	0	3	0	0	3	0	0	0	0
B3	2	4	0	0	1	1	0	2	1	1
B4	1	2	2	0	0	0	4	0	0	0
B5	1	2	3	0	0	3	0	2	2	2
B6	0	1	3	0	0	0	0	0	0	0
B7	0	2	2	4	2	0	0	0	1	0
B8	2	2	2	0	0	2	0	0	0	3
B9	3	3	4	0	0	3	0	2	0	2
B10	0	3	2	0	0	2	0	0	0	0

Step 6: Then the causal diagraph was created to see the effectiveness of dimensions.

Step 7: Conceptual inconsistency was checked, and necessary modifications were made in the final DEMATEL model.

Results and Discussion

The developed ISM model (as shown in figure 1) indicates that with high driving power 'Lack of awareness and Knowledge' (B4), 'Regulatory Challenges and Government Policies' (B7), 'Infrastructure' (B5) were the most influential barriers which hinder in the adoption of IoT in agriculture, these require more focus to avoid implementation obstacles. With high dependence, 'IoT Privacy and Security (B2), 'Cost' (B3) and 'Interoperability' (B1) were the most influenced barriers.

Table 4 shows cause and effect relationship, it can be seen as 'Lack of awareness and Knowledge' (B4), 'Regulatory Challenges and Government Policies' (B7), 'Infrastructure' (B5), 'Choice of Technology' (B9) and 'Networking Challenges' (B8) belongs

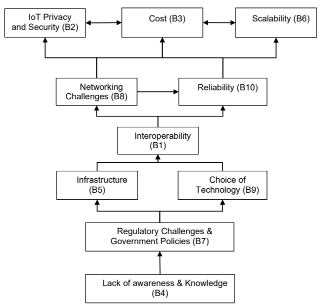

Figure 1: ISM model.

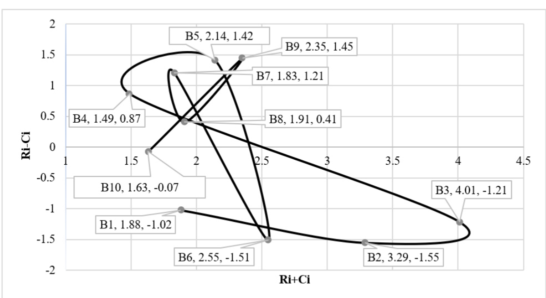

Figure 2: Cause/effect diagram.

Table 4: Cause/effect relationship with validation.

Sl. No.	Barrier	Nature	References
B1	Interoperability	Effect	[16]
B2	IoT privacy and security	Effect	[17]
B3	Cost	Effect	[6]
B4	Lack of awareness and knowledge	Cause	[7]
B5	Infrastructure	Cause	[18]
B6	Scalability	Effect	[7]
B7	Regulatory challenges and government policies	Cause	[5, 6]
B8	Networking challenges	Cause	[18]
B9	Choice of technology	Cause	[6]
B10	Reliability	Effect	-

to the 'Cause' group and 'IoT privacy and security' (B2), 'Cost' (B3), 'Interoperability' (B1), 'Scalability' (B6) and 'Reliability' (B10) belongs to the 'Effect' group. Table 4 also refers to the references to the past research that supports the result.

Conclusion

IoT offers a number of benefits to the Indian agriculture sector by enhancing agricultural productivity and quality of life for small farmers. This study identified critical barriers which were influencing IoT adoption in our country. These identified barriers were further analyzed using a combined ISM-DEMATEL approach, while complimenting each other's results, both methodologies suggest most critical barriers were 'Lack of awareness and Knowledge', 'Regulatory Challenges and Government Policies', 'Infrastructure', 'Choice of Technology' and 'Networking Challenges' in the implementation of IoT. IoT has been certainly the most influential technology in current industries. Our agriculture industry can also gain advantages from it. As discussed in this paper, there are certain obstacles which are restricting our agriculture sector. This paper and previous literature suggests that government related factors play a major role in the implementation of these technologies. Government of India has already taken initiatives in this area, but due lack of knowledge and awareness of the farmers are not able to properly utilize these schemes and policies. Lack of Infrastructure is also a significant barrier in the adoption process, as there is still not proper electricity and Internet connectivity in rural areas. These major factors need more attention in order to implement automation technologies such as IoT in our country. Further research and analysis still need to be done to know the implication of IoT in a better way. Additionally, the ISM model (Figure 1) and cause effect diagram (Figure 2) were developed to comprehend the results of this study. A further result was validated by experts and past research done in related areas (references are mentioned in table 4) based on the findings of this paper, For the successful adoption of IoT in the Indian agriculture sector, these crucial barriers must be addressed and removed.

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Conflict of Interest

None.

Credit Author Statement

Satyam Bhardwaj and Manish Gupta: Study design, Experimentation, Data analysis; Shivam: Writing - original draft preparation, Writing - review and editing. All the authors read and approved the manuscript.

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