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Modeling the internet of things adoption barriers in food retail supply chains

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ABSTRACT

Internet of things (IoT) is estimated to play a significant role in offering tangible and commercial benefits to the supply chains making the operational processes more efficient and productive. IoT system provides the decision-makers with new insights on the value proposition, value creation, helping them to strengthen their bond with the customers and adopt a more effective policy and practices. The food retailing scenario is becoming more complex and flexible putting pressure on the retailing firms to re-design their marketing strategies incorporating the changing consumer behavior. The IoT is expected to help the retailers in controlling the quality of food products, plan waste management of the items that have exceeded their shelf life, manage the temperature at the store, freezers and other equipment's contributing to the reduction of energy consumption. Despite the vast potential of IoT in food retail supply chains, the adoption of IoT is still in its nascent stage. Therefore, this study attempts to identify the various barriers that affect the adoption of IoT in the retail supply chain in the Indian context and also investigates the inter-dependences between the factors using a two-stage integrated ISM and DEMATEL methodology. Lack of government regulations and poor internet infrastructure were identified to be the significant drivers for IoT adoption.

1. Introduction

Internet of Things (IoT) is a rising technological platform that is widely spread in an embedded network of intelligent and autonomous devices, aimed to increase productivity, efficiency and profitability using predictive analysis and big data technologies (Kamble et al., 2018b; Wong and Kim, 2017; Rose et al., 2015). IoT has virtually digitized the physical business ecosystem into an advanced and smart entity. Conceptually, IoT through error-free networks aims to connect any “Thing” independent to place, time and motion (Baldini et al., 2018) that results in more agile manufacturing operations and efficient collaboration among stakeholders. IoT enables a robust and secure way of information exchange in both goods and services supply chains (Arunachalam et al., 2018; Haddud et al., 2017). Industrial firms are getting momentum across a wide range of strategic gains across different technologies. Most notably, they see strategic benefits in robotics, autonomous vehicles, the Internet of Things (IoT) and connected devices, and Industrial IoT platforms (Gartner, 2018).

Worldwide, 50 billion devices shall be part of the IoT network by the year 2020 (DHL, 2015). It is estimated that IoT shall bring an average economic inflow of $7.5 Trillion a year by 2025 across all supply chains (Mckinsey, 2015). Industries have witnessed IoT’s impact on five primary drivers namely: design and innovation, asset utilization and revenue planning, supply chain and logistics design, resource productivity enhancement and extension of stakeholders experience. The adoption of IoT in operations and supply chain offers tangible commercial benefits including, enhanced operational processes, low risk, and cost. The additional benefits include visibility, transparency, adaption, flexibility, and virtualization across the supply chains. (Mineraud et al., 2016; Mishra et al., 2016; Monostori et al., 2016; Trappey et al., 2017; Khan et al., 2018).

With the overall emergence of IoT technology, no industry is excluded from its impact, although the broader applications can be seen in retail business (Pantano et al., 2018; Pantano and Timmermans, 2014). IoT devices in the retail industry primarily consist of smart “Things” that are typically embedded with electronic circuits to channel information using smart devices (Balaji, and Roy, 2017). The retailers are working on developing a new digital eco-system with the use of connected devices to offer new products and services, and improved customer experience (Gregory, 2015; Brynjolfsson et al., 2009). The

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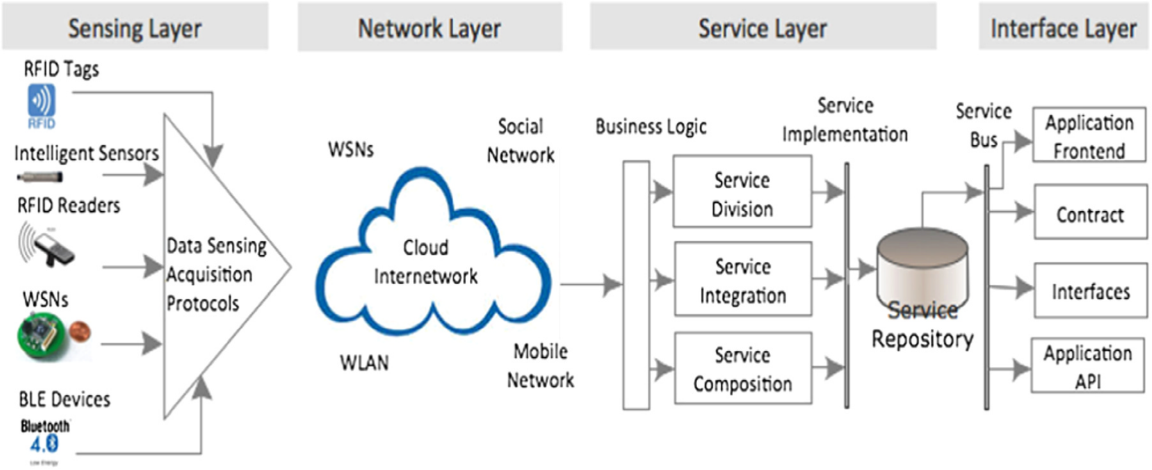

Fig. 1. Service oriented architecture for IoT. Source: Li et al. (2015).

decision-making process in the retail industry is transforming from non-sequential information-processing mode to data-driven decision making, making it obvious to use the IoT applications (Lee and Lee, 2018; Patil, 2016; McFarlane and Sheffi, 2003). IoT facilitates the acquisition of new capabilities, from the perspective of management and control. The data released from IoT system provides the decision-makers with new insights on the value proposition, value creation, helping them to strengthen their bond with the customers and adopt more effective policy and practices (Sharma et al., 2018; Bressanelli et al., 2018; Balaji and Roy, 2017). Despite the tremendous potential of IoT providing an interactive platform for real-time interactions between the involved stakeholders that consists the suppliers, retailers, customers etc., with the products and services resulting in enhanced personalized retail experience for the customers (McFarlane and Sheffi, 2003; Gregory, 2015; Lee and Lee, 2015; Balaji and Roy, 2017), in India, the IoT adoption in retail business is in very initial stage (Patil, 2016). More specifically, the literature lack studies on IoT adoption in food retailing. The study of IoT adoption in food retailing is more relevant at this stage because the physical retail stores are facing intense competition from the e-retailers (Helm et al., 2018; Kumar, 2018). The retail stores should focus on adopting simple and smart technologies that contribute towards enhancing customer value and shopping efficiency (Roy et al., 2018). Implementing IoT is expected to help the physical stores to overcome the challenges posed by online retailers (Barnawal and Pateriya, 2016; Barmpounakis et al., 2015). Presently, the practitioners in the retail sector acknowledge the benefits of IoT in their supply chains and are in the state of readiness to adopt this technology. However, they face many challenges in the absence of robust frameworks that guide IoT implementation in food retailing. There exist various concerns and barriers in implementing IoT in logistics and supply chain management, from both techno-managerial perspectives (Ben-Daya et al., 2017; Haddud et al., 2017; Hsu and Yeh, 2017). It is therefore essential to remove these obstacles (barriers) for effective implementation of IoT in the food retailing industry. This present study is one of the preliminary studies that attempt to explore and study the mutual relationship between the various IoT implementation barriers in the food retailing context. The primary objective of this study is to identify the dominant barriers of IoT implementation in food retail stores and investigate the causal relationship among barriers using an “Interpretive Structural Modeling” (ISM) and “Decision-making trial and evaluation laboratory “ (DEMATEL) technique. The remaining of the paper is organized as follows. Section 2 briefly reviews the literature on IoT and food retailing. Section 3 discusses the research methodology adopted for the study. Section 4 discusses the detailed implementation of the ISM and DEMATEL techniques in food retail industry and presents the findings. The discussion on the results and the implications are presented in Section 5. Section 6 presents the conclusions and limitations of the study.

2. Review of literature

2.1. Internet of Things (IoT)

The IoT explains a broader platform in which internet has evolved itself into a real-world application using routine and daily objects.

The physical items such as machines, equipment, products at various stages, etc., existing at different and remote locations are connected virtually with each other. These devices, acting as physical access points are monitored and controlled through cyber systems (Mattern and Floerkemeier, 2010; Haller, 2009; Gubbi et al., 2013; Kelly et al., 2013; Lee and Lee, 2015). Conceptually, IoT is an active network infrastructure having capabilities to self-configure itself based on standard and interoperable, protocols (Ferretti and Schiavone, 2016). IoT recognizes every entity as “Things” having basic physical properties including physical characteristic, a virtual existence and intelligent interfaces that flawlessly incorporate them into the information system (Tan and Wang, 2010; Xu et al., 2018). As all the things in the system are connected, the IoT system architecture must ensure the seamless integration of this cyber-physical interface (Li et al., 2015). IoT architectures involve a variety of factors including a set of connections, announcement, business models and processes, and security (Ulmer et al., 2013; Van Looy et al., 2014). While designing the IoT architecture, various factors that include extensibility, scalability, and interoperability needs to be considered for smooth transition and integration of the existing heterogeneous network devices spread across the entire supply chain (Li et al., 2015). A typical “service-oriented architecture” (SOA) of IoT is illustrated in Fig. 1.

As seen in Fig. 1 the four layers include:

i. *Sensing layer*, which is combined with the hardware (including, Radio Frequency ID, sensors, actuators), to sense and control the physical systems and collect the data.
ii. *Networking layer*, virtually integrate every entity and share the information across each other by providing necessary networking support and data transmission.
iii. *Service layer*, generate and control services based on underlined technology providing functionalities to incorporate services and applications in IoT flawlessly.
iv. *Interface layer* facilitates interaction between users and other applications.

Table 1
IoT technologies.

IoT Technology	Description
IoT Security	The IoT systems are interacting to Trillions of devices across the world, that increases the usual risks of data use (Kamble et al., 2018b). 21 Billion IoT devices are going to be invaded by 2020, the primary reason behind it is high risk if cyber attacks and data thefts (Eddy, 2015). Therefore, there is an instant need to enhance the trustworthiness and standardization.
IoT Analytics	The IoT captures voluminous data (big data) in real time that is high in variety and needs to be analyzed using modern analytical tools and algorithms (Mikusz et al., 2015).
IoT Device Management	The organizations must be having the capability of aligning thousands or maybe millions of devices connected (Perumal et al., 2015).
Low energy IoT Networks	It is estimated that by 2025, low-energy networks will be preferred over the wireless IoT connectivity (Bulusu et al., 2000)
Low-Power, Wide-Area Networks	Futuristic standards such as Narrowband IoT (NB-IoT) is expected to dominate the IoT space because of its capability to deliver high-speed communication with nationwide coverage, and higher battery life. (Raza et al., 2017).
IoT Processors	Processors that can provide a robust security and encryption solution, low power utilization IoT system, supporting an operating system and firmware will be in demand. (Wang et al., 2015; Haddud et al., 2017)
IoT Operating Environment	The IoT operating environment should cater to the requirements of different hardware configurations (Hahm et al., 2016; Haddud et al., 2017)
Distributed Stream Processing	Platforms are required to support Distributed Stream for analyzing the data in real time. These platforms are based on the parallel computing architectures. (Nissam et al., 2017; Haddud et al., 2017)
Platforms	IoT infrastructure system components under the platforms should ensure efficient device management, control and operations that includes the aspects of data acquisition, storage analysis, and sharing (Lucero, 2016; Gartner, 2016; Jia et al., 2017; Haddud et al., 2017).
IoT Standards and Ecosystems	As interoperability and communication are the two main features of an IoT system, standards and application programming interfaces (API's) will be essential (Vermesan and Friess, 2013; Haddud et al., 2017)

2.2. Internet of things technologies

The RFID system is the base technology for IoT which facilitate a circuit to broadcast the information to an end user through a secure system network. Other methodologies adopted by IoT include barcoding, embedded devices, intelligent sensors, internet protocols and applications (Al-Fuqaha et al., 2015; Haddud et al., 2017; Ojha et al., 2015; Da et al., 2014). RFID is widely used in industries, including, warehousing, retailing, and logistics (Jia et al., 2012; Lim et al., 2013; Zeng, 2015; Haddud et al., 2017). IoT is inevitably set to become one of the top preferred technologies in the organizations, and therefore, the following techniques as shown in Table 1 would be on the priority list of the organizations.

IoT is a disruptive technological innovation that is expected to significantly influence the future information technology integration and optimization (Vermesan and Friess, 2013; Kang et al., 2016). The trends of this technology are far-reaching, covering all major industries and business sectors. However, the perceived adoption and diffusion of the IoT is in a nascent stage. There is still devoid of acknowledgment about IOT and clarification 'adaptive strategies' for industries to unleashed its benefits (Rad and Ahmada, 2017; Hsu and Yeh, 2017).

2.3. Internet of things in food retailing

The food shopping in India is mostly done at the physical stores, because of the need by the consumers to feel, smell and even test the product at the time of shopping. Further, the consumers also believe in buying their food products, not trusting others to make the buying decision. Overall the food shopping is categorized as an impulse buying item with the customers viewing it as a pleasurable experience. The digital technologies such as IoT enhances the shopping experience of the consumers making it more personalized, convenient and engaging (Gregory, 2015). The retailing scenario is becoming more complex and flexible and hence puts pressure on the food retailing firms to re-design their marketing strategies incorporating the changing consumer preferences (Maruyama et al., 2016). IoT in food retailing can help the consumer and the salespersons to locate the product quickly, display the product details and nutritional value with the help of sensors on the products, flash the latest price and promotional offers. The IoT also plays a vital role in tracking the logistical movements of the food items, reducing the delivery lead times which is highly critical for managing products with less shelf life. Also, the IoT is expected to help the retailers in controlling the quality of food products, plan waste management of the items that have exceeded their shelf life, manage the temperature at the store, freezers and other equipment's contributing to the reduction of energy consumption. The RFID technologies help the retail stores for improvements in the category management, efficient design of store layouts, product replenishment and inventory management (Pantano and Timmermans, 2014). The literature argues that retailers acceptance plays a vital role in the commercial success of IoT technology (Huang and Liao, 2015; Pantano and Servidio, 2012; Tsai et al., 2010) providing an understanding on the IoT adoption drivers. Kaloxylos et al. (2013) proposed ICT support system for the agricultural sector for improving the level of communication between its key stakeholders that included farmers, logistics service providers, and retailers. Verdouw et al. (2016) discussed the application of IoT in improving the retailing process of the fish supply chain. Other studies on application IoT in a food supply chain includes an automated food traceability system (Chen, 2015) and food contamination monitoring system (Seo et al., 2016).

2.4. Information sharing standards in the food supply chain

The traceability in food retailing enables the organizations to trace the history of the food products through recorded transactional information. The traceability requires that the required information is shared across all the supply chain points in a standard language (Fritz, 2009). GS1 (formerly, EAN, UCC) system is one of the most promising standards used for information sharing across the supply chains, ensuring continuity of the product traceability from producer to the retailer (Zhao et al., 2011; Bai et al., 2017). GS1 system has three main components namely: i. Standard numbering structures, ii. Data carriers (usually barcodes) and iii. E-messaging standards. The captured data is in a machine-readable format that is interchanged with the other parties in the supply chain using e-messaging standards. HACCP (Hazard Analysis and Critical Control Points) is another such approach that is widely acknowledged for ensuring food quality and safety. HACCP analyzes and controls the hazards at key food supply chain points such as producers, processors, distributors, and retailers. However, the main limitation of this approach is that the HACCP is performed independently at the various supply chain points with the data residing at these locations. The HACCP data is not shared unless until requested by the other parties in the supply chain (Zhao et al., 2011). GS1 standards complements the HACCP systems by facilitating the HACCP information sharing across the food retail supply chains (Tian, 2016). The combination of the HACCP and GS1 can guarantee quality and safe food products to the retail customers, providing the information transparency and the tracking details of the food products. The GS1 standards offers the following benefits to the retailers: reduced inventory levels, improved order and invoice accuracy, reduced lead times, high customer service level, improved traceability of the items (IBM, 2012; Semianiaka and Silina, 2012). The food retail chains can adopt the GS1 and HACCP system to enhance information communication quality. This integration will help to automate the supplier and the retailer transactions, improving the data accuracy and simplify the invoice processing. The capability of the retail stores in tracing the products back to its origin on receipt of any customers complaints or food-related accident increases exponentially with the adoption of HACCP and GS1. It is identified from the literature that there are no common standards for the data collection and sharing in IoT, restricting its adoption in different application scenarios (Tseng et al., 2015, 2016).

2.5. Internet of things adoption barriers (IoTB)

IOT is believed to have an immense impact on the global economic platform in the next decade (Löffler et al., 2016; Bauer et al., 2015). It is indicated that the transformation and optimization of the global economy will solely depend on the adoption scale of IoT devices, affordability, and durability of smart devices and technology acceptance scale for consumers as well as workers (Rad and Ahmada, 2017). The study examined the available literature to identify the possible IoT adoption barriers. We identified twelve potential barriers which are discussed as below.

2.5.1. Lack of government regulations

Legal information systems need to evolve to support massive development and expansion of IoT in logistics and SCM as this will ensure security standards and regulate its operation. Judicial laws should provide guidance on the efficient use of energy, developing network capacity, and network usage clearly defining the restrictions on sensitive frequency bands (Bandyopadhyay and Sen, 2011). Government, institutions, and organizations must concurrently work together in promoting and supporting technological initiatives and solutions (Rose et al., 2015). More specifically government rules and regulations should also address the changing dynamics of the Indian retail industry, considering a large number of small and unorganized retailers contributing to this sector (Sebastian and Gupta, 2018).

2.5.2. Lack of standardization

IoT communication protocol established global standards for smart objects and systems that ensure smooth and efficient integration between various vendors and data safety over the entire IOT network. The existence of global standards makes IoT capable of handling sensitive devices, cloud networks and the end user platform (Pang et al., 2015). Standardization is useful for information interchanging between the device and its digital counterparts in the virtual cloud to compose, control and survey thing (Bandyopadhyay and Sen, 2011). IoT incorporates a variety of standards (*including,* identification, communication, and security) that plays a critical role in the successful implementation of IoT. Researchers in the past have identified lack of standardization as a common adoption barrier for most of the new technologies (Tan and Koo, 2014; Riggins and Wamba, 2015).

2.5.3. High energy consumption

Efficient power consumption is a contemporary topic arising as it is the critical area of concern for IOT implementation. Energy-efficiency is the essential criteria for an active IoT device (Borgia, 2014). Primarily in the commercial application of IoT in logistics and SCM, power is a significant concern, and therefore, passive tag RFIDs which do not have a power source are more preferred. The system power consumption can be enhanced while lowering the power usage of electronic module by various alternative power storage devices as a substitute for rechargeable usage which will mutually reflect in the life cycle of devices. With the increasing number of IoT devices, networks, and data centers, there will be a growing demand for energy, and hence it is expected that the energy costs of these supply chains will be continuously increasing (Sethi and Sarangi, 2017).

2.5.4. Security and privacy

Security is imperiled in the network-based system because of the threats like overwriting false data, accessing sensitive data and many other unauthorized intrusions which may paralyze the networks (Navajo et al., 2010). Particular issues including access, security, and privacy become areas of concern (Wang et al., 2013; Li et al., 2013; Xing et al., 2013). RFIDs are more prone to these attacks due to its limitation on applied intelligence enabling them for the person and object tracking (Juels, 2006). Issues related to encryption of data, internet connectivity, software protection, and authorization, make the IoT system vulnerable to external security risks (Lee and Lee, 2015; Reaidy et al., 2015; Riggins and Wamba, 2015; Haddud et al., 2017). Li et al. (2015) summarize the challenges in security and privacy protection, as resilience to attacks, data authentication, access control, and client privacy.

2.5.5. High operating and adoption costs

The implementation of IoT solutions requires high-end technical infrastructure support (Haddud et al., 2017). There exist a technological risk related to financial loss and irreversibility of investments to organizations (Ericsson, 2016; Lee and Lee, 2015; Pang et al., 2015; Decker et al., 2008). In the future, these devices will raise concern for their repair and maintenance (Chen et al., 2014). Organizations must understand the financial returns on IoT investments vis-à-vis the investments made on implementing them.

2.5.6. Long payback period

The IoT implementation in the industries involves a vast range of sensing and actuating devices, increasing the cost of investments. Depending on the size of IoT implementation and the finances made, the returns on investment may take a longer time than expected, thus increasing the payback period (Luthra et al., 2018; Granjal et al., 2015).

2.5.7. Lack of internet infrastructure

Poor internet connectivity and electricity problems are identified as one of the critical challenges to IoT adoption (Luthra et al., 2018; Bedekar, 2017). The internet is not only required at the retail outlet but has to available with all the supply chain partners. In a food supply chain, most of the supply chain partners are located at remote locations, for example, a retail outlet directly sourcing food grains from a farmer located in a village with low internet penetration and issues with continuous supply of electricity cannot expect to have a real-time flow of information.

2.5.8. Lack of human skill availability

IoT system requires highly trained professionals to develop and implement practical applications (Hussain et al., 2016; Hung, 2016). The interface, installation, and management of IoT network should be user-friendly to ensure adaptability of the system (Talavera et al., 2017) for which high end technical and functional skills are required (Ryan and Watson, 2017; Guarda et al., 2017).

2.5.9. Seamless integration and compatibility issues

Due to heterogeneity in the adoption of technologies, integration and compatibility problems prevail while adopting IoT into a system. (Alaba et al., 2017; Da et al., 2014; Ghashghaee, 2016; Hussain, 2016). Challenges in integrating IoT technologies with existing legacy systems within supply chains act as the barrier for IoT adoption (Bi et al., 2014; Bughin et al., 2015; Riggins and Wamba, 2015). Designing of modular hardware and software will ensure greater compatibility also will provide flexibility and customization according to the user requisition. (Pang et al., 2015). Compatibility with the current industrial automation that includes the software, hardware, vehicle, and other composed machinery and equipment is essential for the smooth integration between systems (Talavera et al., 2017).

2.5.10. Scalability issues

With the increasing size of the IoT network, with more number of physical devices estimated to get connected in future, scalability will be a significant issue to be addressed as the organizations have to keep themselves updated to manage the problems related to increasing complexities pertaining to data collection, storage, processing, analysis, and service provisioning (Da et al., 2014; Miorandi et al., 2012: Diedrichs et al., 2014).

2.5.11. Lack of validation and identification

The literature for improvement and development in IOT based systems majorly covers functional and technological challenges. There is a scarcity of research on multi-applications in industries and are still in the nascent stage (Talavera et al., 2017; Ryan and Watson, 2017). Very few IoT adoption shows clear returns across the industrial sector that discourage small and independent business enterprises to adopt such disruptive, innovative technology (Haddud et al., 2017; Da et al., 2014; Lee and Lee, 2015; Ryan and Watson, 2017).

2.5.12. Architecture

Initial planning, design, and selection of an IoT architecture, aiming for different applications become a critical challenge particularly in the case of wireless systems. An efficient system architecture across the Supply Chains includes a variety of objects, support systems and end-user applications (Haddud et al., 2017). Similar challenges are discussed in the literature (Bi et al., 2014; Bughin et al., 2015; Jin et al., 2014; Li et al., 2015).

3. Research methodology

This study has used a two-phase hybrid methodology uniting the ISM and DEMATEL. The ISM method was used to describe the relationship among various factors by a multi-level hierarchical structure, making the complex relationships clear, as well as prioritizing the selected factors. The use of DEMATEL helped us to measure the interactive effects of the factors chosen quantitatively. The details of the ISM and DEMATEL are given as follows.

3.1. Interpretative structural model

Warfield (1974) proposed ISM to relate attributes in a comprehensive framed model. ISM method embraces an interactive learning process in which a set of disparate and elements directly related are arranged to form a comprehensive systematic model (Mudgal et al., 2009; Sage, 1977; Patel et al., 2018). The developed model, depicts the configuration of a complex problem, a system or a discipline of study, in a prudently designed pattern implying graphics, words and discrete mathematics employed as multi-criteria decision making tool for interactions and interrelationships (Mathiyazhagan et al., 2013; Attri et al., 2013; Malone, 1975; Ravi and Shankar, 2005). The basic idea of ISM is to use experts' applied expertise, experience and knowledge to split a complex system into numerous subsystems (elements) and develop a multi-level structural model (Agarwal et al., 2007; Jindal and Sangwan, 2013). ISM augments direct and indirect relationships which show higher accuracy than the factors considered in isolation with each other Cagno et al. (2014).

3.1.1. ISM process

The step-wise description of the ISM model applied in the study are as follows (Kannan and Haq, 2007; Kamble et al., 2018a):

Step 1: The IoTB's are identified with the help of a literature review and experts' opinion
Step 2: A relationship among all the identified IoTBs is established
Step 3: For developing a pair-wise relationship among adoption barriers, a structural self-interaction matrix (SSIM) is devised. Four symbols are utilized to represent the direction of the relationship between the adoption barriers (i and j)

V: When the IoTB$_i$ influences IoTB$_j$;
A: When the IoTB$_i$ gets influenced by IoTB$_j$
X: When both the IoTB's influences each other; and
O: When the IoTBs do not influence each other.

Step 4: An initial reachability matrix is developed using the inputs from SSIM, and the same is tested for the transitivity. The initial reachability matrix is a binary matrix developed by converting the symbols V, A, X and O used in the SSIM into binary values 0 and 1 as per the following guidelines;

The symbol used in SSIM	Conversion in initial reachability matrix
V	The (i, j) entry is converted to 1, and the corresponding (j, i) entry is converted to 0.
A	The (i, j) entry is converted to 0, and the corresponding (j, i) entry is converted to 1.
X	The (i, j) entry is converted to 1, and the corresponding (j, i) entry is also converted to 1.
O	The (i, j) entry is converted to 0, and the corresponding (j, i) entry is also converted to 0.

The final reachability matrix is developed after checking for the transitivity as per the following rule: if a barrier 'P' is related to 'Q' and 'Q' is related to 'R' then 'P' is similar to 'R.'

Step 5: The final reachability matrix developed in step 4 is partitioned into various levels.
Step 6: A directed graph (digraph) is developed using the values obtained in the final reachability matrix as developed from step 5 and transitive links are eliminated from it.
Step 7: Nodal elements are replaced by statements, the developed digraph is transformed into the ISM model for IoT adoption barriers.
Step 8: The established model is reviewed and tested for any conceptual inconsistencies.

3.2. DEMATEL

The DEMATEL is grounded on matrices that exemplify the contextual relation and also the intensity of elements' influence of the target system. It transforms the cause-effect relationship of elements into observable structural models. Due to it the applied benefits the DEMATEL has been extensively useful in many fields, like marketing (Shieh et al., 2010; Tseng, 2009;), education (Chen and Chen, 2010; Tzeng, Chung-Wei, 2007), supply chain management (Chang et al., 2011; Patil and Kant, 2013), waste management (Chauhan et al., 2018), technology management (Chaghoshi et al., 2016). The DEMATEL method has advantages that help researchers better understand the nature of the problem.

3.3. DEMATEL process

Mathematically, the procedures of DEMATEL are narrated step-by-step as follows; (Shieh et al., 2010; Amiri et al., 2011; Sumrit and Anuntavoranich, 2013).

Step 1: Computation of average matrix

For the data collection part, each respondent from the group of experts considered for SSIM was requested to assess the direct influence among any two success factors with an integer value ranging from 0, 1, 2, and 3, respectively. 0 represented “no influence,” 1 represented “low influence,” 2 represented “medium influence,” and 3 represented “high influence,” respectively. (The notation of x_{ij}signifies the degree for which the respondent considers factor *I* affects factor *j*.

For $i = j$, the diagonal elements are set to zero. An n x n non-negative matrix for each respondent can be created as $X^k = [x^k_{ij}]$, where k is the number of respondents with $1 \le k \le H$, and n is the number of factors. Thus, X^1, X^2, X^3, …, X^H are the matrices from H respondents. To integrate all opinions from H respondents, the average matrix A= $[a_{ij}]$ can be created as

$$a_{ij} = 1/H \sum_{k=1}^{H} x_{ij}^{k}$$

Step 2: Calculation of the normalized initial direct- relation matrix

Normalize initial direct- relation matrix D by $D = A \times S$, where $S = 1/\, max_{1\le i\le n} \sum_{j=1}^{n} a_{ij}$. Each element in the matrix D ranges from zero and one.

Step 3: Calculation of the total relation matrix.

The total relation matrix T is defined as $T = D\ (I\text{-}D)^{-1}$, where I is the identity matrix.

Let vector R be (n x 1), and D be (1 x n). Thus, the sum of the row would be calculated as:

$(D_1 \ldots D_n)$ with $D_j = \sum_{i=1}^{n} t_{ij}$where $(j = 1, 2, \ldots, n)$

The sum of the column is calculated as follows:

D_1

$[D_2]$ with $D_i = \sum_{j=1}^{n} t_{ij}$where $(i = 1, 2, \ldots, n)$

D_n

The sum of columns represents the direct and indirect effect of factor i on the other factors. Similarly, if Rj is the sum of the jth column in the matrix T, then:

R_1

$[R_2]$ with $R_i = \sum_{j=1}^{n} t_{ij}$where $(i = 1, 2, \ldots, n)$

R_n

The sum of rows represents the direct and indirect effects the factor j receives from the other factors. When i = j, the sum (Di + Ri) shows the total effects given and received by factor i, thus:

$$(D_i + R_i) = \sum_{j=1}^{n} t_{ij} + \sum_{k=1}^{n} t_{ik}$$

It represents the degree of importance of factor i in the entire system. The difference indicates the net effects that factor i contributes to the system and is shown below:

$$(D_i - R_i) = \sum_{j=1}^{n} t_{ij} - \sum_{k=1}^{n} t_{ik}$$

Specifically, if (Di – Ri) is positive, the influence factor i is a net cause, while if (Di – Ri) is negative, factor i is a net receiver.

Step 4: Drawing the impact relation map.

The last step in DEMATEL is drawing the impact relation Map. All coordinate sets of (Di + Ri, Di – Ri) are mapped to visualize the complex interrelationship. This diagram provides information to the researcher of which are the most significant factors that influence the decision making (Shieh et al., 2010).

4. Study and data analysis

The detailed procedure for ISM and DEMATEL used to analyze the relationship between the IoT adoption barriers in the retail food business is discussed in this section. The ISM is described first followed by MICMAC analysis and DEMATEL.

4.1. ISM model development

The ISM applied for understanding the relationship between the barriers in the retail business is described below.

4.1.1. Selection of IoTBs

The significant IOTBs in supply chains are identified using secondary data and expert opinion from the study domain (Kamble et al., 2018a). The pool of journals referred for the review range from various databases including, Web of Science, Scopus, IEEE Explore, Emerald Insight, and Sage Publications. The secondary data from other sources such as conference proceedings, book chapters, newspapers, magazines, and corporate white papers were also considered. The identified IoTBs were validated by twelve practitioners from the field of technology, computer, and supply chain. Two of them were senior professors having more than eight years of teaching experience in retail supply chain management, four of them were high-level system integrators having worked in the domain of IoT implementation in retail chains, four of them were senior-level industry practitioners representing two retail chains located in Mumbai, India, one expert was data analyst with the four years experience in big data analytics and one executive manager from the domain of IT security. The demographic profile of the selected experts is presented in Table 2.

Twelve IoTBs were shortlisted for the final study as discussed in Section 2.4. The same group of experts was approached for their responses on the various IoTBs for developing the SSIM. The authors based in India moderated the discussions and compiled the collected information for preparing the SSIM. The authors ensured that the number of selected experts (twelve experts) for IoTB validation and qualitative survey was within the recommended range of 10–50 (Chauhan et al., 2018; Robbins, 1994; Murry and Hammons, 1995).

4.1.2. Development of SSIM

The responses collected from the experts were used to develop the SSIM as shown in Table 3 (Chauhan et al., 2018; Mangla et al., 2018; Malviya and Kant, 2017). The procedure for obtaining the SSIM is elaborated in step 3 of the ISM process (See Section 3.1.1).

Table 2
Demographic profile of the selected experts.

Profile Variables	**Number (N = 12)**
Gender	
Male	*8*
Female	*4*
Age	
Below 40 years	*1*
40–50 years	*6*
51 years and above	*5*
Education	
Bachelor	*1*
Master	*8*
Doctorate	*3*
Experience in their field	
Less than five years	*1*
5–10 years	*2*
10–15 years	*6*
15 years and above	*3*
Domain of expertise	
Academics (supply chain management)	*2*
System integration	*4*
Data analyst	*1*
Data Security	*1*
Retail Management (Practitioners)	*4*

Table 3
SSIM.

IoTB's	IoTB12	IoTB11	IoTB10	IoTB9	IoTB8	IoTB7	IoTB6	IoTB5	IoTB4	IoTB3	IoTB2	IoTB1
IoTB1	X	X	X	A	V	V	A	A	A	V	V	
IoTB2	A	A	A	A	X	V	A	A	A	X		
IoTB3	A	A	A	A	X	V	A	A	A			
IoTB4	A	V	V	O	V	V	V	A				
IoTB5	V	V	V	V	V	V	V					
IoTB6	A	X	X	A	V	V						
IoTB7	A	A	A	A	A							
IoTB8	A	A	A	A								
IoTB9	V	V	V									
IoTB10	X	X										
IoTB11	X											
IoTB12												

IoTB1: Complex architecture, IoTB2: High energy consumptions, IoTB3: High operating costs, IoTB4: Lack of human skills, IoTB5: Lack of regulations and governance, IoTB6: Lack of standards, IoTB7: Lack of validations, IoTB8: Long payback period, IoTB9: Lack of internet infrastructure, IoTB10: Scalability issues, IoTB11: Integration and compatibility issues, IoTB12: Security and privacy issues.

Table 4
Initial reachability matrix.

IoTB's	IoTB1	IoTB2	IoTB3	IoTB4	IoTB5	IoTB6	IoTB7	IoTB8	IoTB9	IoTB10	IoTB11	IoTB12
IoTB1	1	1	1	0	0	0	1	1	0	1	1	1
IoTB2	0	1	1	0	0	0	1	1	0	0	0	0
IoTB3	0	1	1	0	0	0	1	1	0	0	0	0
IoTB4	1	1	1	1	0	1	1	1	0	1	1	0
IoTB5	1	1	1	1	1	1	1	1	1	1	1	1
IoTB6	1	1	1	0	0	1	1	1	0	1	1	0
IoTB7	0	0	0	0	0	0	1	0	0	0	0	0
IoTB8	0	1	1	0	0	0	1	1	0	0	0	0
IoTB9	1	1	1	0	0	1	1	1	1	1	1	1
IoTB10	1	1	1	0	0	1	1	1	0	1	1	1
IoTB11	1	1	1	0	0	1	1	1	0	1	1	1
IoTB12	1	1	1	1	0	1	1	1	0	1	1	1

IoTB1: Complex architecture, IoTB2: High energy consumptions, IoTB3: High operating costs, IoTB4: Lack of human skills, IoTB5: Lack of regulations and governance, IoTB6: Lack of standards, IoTB7: Lack of validations, IoTB8: Long payback period, IoTB9: Lack of internet infrastructure, IoTB10: Scalability issues, IoTB11: Integration and compatibility issues, IoTB12: Security and privacy issues.

4.1.3. Development of initial reachability matrix

Using the procedure as illustrated in step 4 (See Section 3.1.1) the SSIM is transformed to develop the initial reachability matrix as shown in Table 4.

Transitivity has been incorporated in the ISM process as per step 4 (See Section 3.1.1). The final reachability matrix is exhibited below in Table 5. The transitivity process was executed using a software program developed in MATLAB (Kamble et al., 2018a).

4.1.4. Level segmentation

The reachability set, antecedent set and the intersection sets obtained from the final reachability matrix were used to arrive at the hierarchical levels. The IoTBs for which the reachability and intersection sets are same is the top-level IoTB in the ISM hierarchical level. The top-level IoTBs in the hierarchy would not help achieve any other IoTBs above its level. After the top-level IOTBs are identified, these are segregated from the other IoTBs, and new levels are determined. The iterations used to arrive at all the hierarchical levels are shown in Table 6. The twelve IoTBs were classified in five hierarchical levels. The

Table 5
Final reachability matrix.

IoTB's	IoTB1	IoTB2	IoTB3	IoTB4	IoTB5	IoTB6	IoTB7	IoTB8	IoTB9	IoTB10	IoTB11	IoTB12
IoTB1	1	1	1	1	0	1	1	1	0	1	1	1
IoTB2	0	1	1	0	0	0	1	1	0	0	0	0
IoTB3	0	1	1	0	0	0	1	1	0	0	0	0
IoTB4	1	1	1	1	0	1	1	1	0	1	1	1
IoTB5	1	1	1	1	1	1	1	1	1	1	1	1
IoTB6	1	1	1	1	0	1	1	1	0	1	1	1
IoTB7	0	0	0	0	0	0	1	0	0	0	0	0
IoTB8	0	1	1	0	0	0	1	1	0	0	0	0
IoTB9	1	1	1	1	0	1	1	1	1	1	1	1
IoTB10	1	1	1	1	0	1	1	1	0	1	1	1
IoTB11	1	1	1	1	0	1	1	1	0	1	1	1
IoTB12	1	1	1	1	0	1	1	1	0	1	1	1

IoTB1: Complex architecture, IoTB2: High energy consumptions, IoTB3: High operating costs, IoTB4: Lack of human skills, IoTB5: Lack of regulations and governance, IoTB6: Lack of standards, IoTB7: Lack of validations, IoTB8: Long payback period, IoTB9: Lack of internet infrastructure, IoTB10: Scalability issues, IoTB11: Integration and compatibility issues, IoTB12: Security and privacy issues.

Table 6
Final level partitions.

Iterations	Reachability Set	Antecedent Set	Intersection Set	Level
Iteration No. 1	1,2,3,4,6,7,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	2,3,7,8	1,2,3,4,5,6,8,9,10,11,12	2,3,8	
	2,3,7,8	1,2,3,4,5,6,8,9,10,11,12	2,3,8	
	1,2,3,4,6,7,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	1,2,3,4,5,6,7,8,9,10,11,12	5	5	
	1,2,3,4,6,7,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	7	1,2,3,4,5,6,7,8,9,10,11,12	7	I
	2,3,7,8	1,2,3,4,5,6,8,9,10,11,12	2,3,8	
	1,2,3,4,6,7,8,9,10,11,12	5,9	9	
	1,2,3,4,6,7,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	1,2,3,4,6,7,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	1,2,3,4,6,7,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
Iteration no. 2	1,2,3,4,6,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	2,3,8	1,2,3,4,5,6,8,9,10,11,12	2,3,8	II
	2,3,8	1,2,3,4,5,6,8,9,10,11,12	2,3,8	II
	1,2,3,4,6,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	1,2,3,4,5,6,8,9,10,11,12	5	5	
	1,2,3,4,6,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	2,3,8	1,2,3,4,5,6,8,9,10,11,12	2,3,8	II
	1,2,3,4,6,8,9,10,11,12	5,9	9	
	1,2,3,4,6,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	1,2,3,4,6,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
	1,2,3,4,6,8,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	
Iteration no. 3	1,4,6,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	III
	1,4,6,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	III
	1,4,5,6,9,10,11,12	5	5	
	1,4,6,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	III
	1,4,6,9,10,11,12	5,9	9	
	1,4,6,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	III
	1,4,6,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	III
	1,4,6,10,11,12	1,4,5,6,9,10,11,12	1,4,6,10,11,12	III
Iteration no. 4	9	5,9	9	IV
	5,9	5	5	
Iteration no. 5	5	5	5	V

information from Table 6 is used for developing the final ISM digraph as shown in Fig. 2.

4.2. MICMAC analysis

To have more profound insights on the relationships revealed by ISM diagraph," Matriced' Impacts Croise's Multiplication Appliquée a UN Classement" (MICMAC) analysis was used to evaluate the pivot and dependence power values for the selected IoTBs based on the FRM (Table 5). The MICMAC diagram classifies the critical barriers in four clusters namely: Autonomous Cluster, Dependent Cluster, Linkage Cluster and Driving Cluster (Kannan and Haq, 2007; Diabat, Govindan, 2011; Kamble et al., 2018b). The MICMAC diagram plotted for the driving and dependence values of all the IoTBs is demonstrated in Fig. 3.

4.3. DEMATEL model development

The relationship between the twelve IoTBs was established using DEMATEL, computing their degree of influence on each other. Steps 1, 2, 3, 4 and 5 of the DEMATEL process *(See section 3.2.1)* were performed to develop the direct influence matrix, normalized direct influence matrix, total relation matrix and the degree of influences are developed. These findings are shown in Tables 7–10 respectively. Fig. 4 presents the digraph showing the relationship between the IOTBs derived from the degree of influences.

5. Results and discussions

5.1. ISM model

The initial aim of the ISM model was to obtain the hierarchy levels for the IoTBs so that the dependency relationship between these IoTBs are available to the practitioners in the retail food industry, helping them to overcome the barriers for implementing IoT in their food retail business by focusing on the key adoption barriers. The finding of the present study is interesting as it reveals five different hierarchical levels to describe the relationships between the selected IoTBs. At the top hierarchy, we obtained lack of validations (IoTB 7) as the top IoTB, driven by the four hierarchies below it. At the second level, we obtained three IoTBs viz., high energy costs(IoTB 2), high operating costs (IoTB 3) and long payback period (IoTB 8) that are further driven by three hierarchical levels beneath it. At the third level, we have a set of six IoTBs affecting each other. These IoTBs include complex architecture (IoTB 1), lack of human skills (IoTB 4), lack of standards (IoTB 6), scalability issues (IoTB 10), integration and compatibility issues (IoTB 11), and security and privacy issues (IoTB 12). The IoTBs in the level III hierarchy are driven by the IoTBs in level IV (poor internet connectivity (IoTB 9) and level V (lack of regulations and governance (IoTB 5)). The lack of regulations and governance (IoTB 5) was found to have the highest driving power, followed by poor internet connectivity (IoTB 9). These two IoTBs are the most significant barriers and have to be given more attention by the retail supply chain practitioners.

5.2. MICMAC analysis

The findings from the MICMAC analysis shown in Fig. 3 reveals that the twelve IoTBs can be classified into three clusters. The cluster I (autonomous barriers) representing low dependence and low driving power did not include any of the IoTBs indicating that all the selected IoTBsare relevant, connected and have control over the system. The IoTBs namely: lack validations (IoTB 7), high energy consumption (IoTB 2), high operating costs (IoTB 3) and long payback period (IoTB 8) were divided into Cluster II (dependent barriers)indicating high

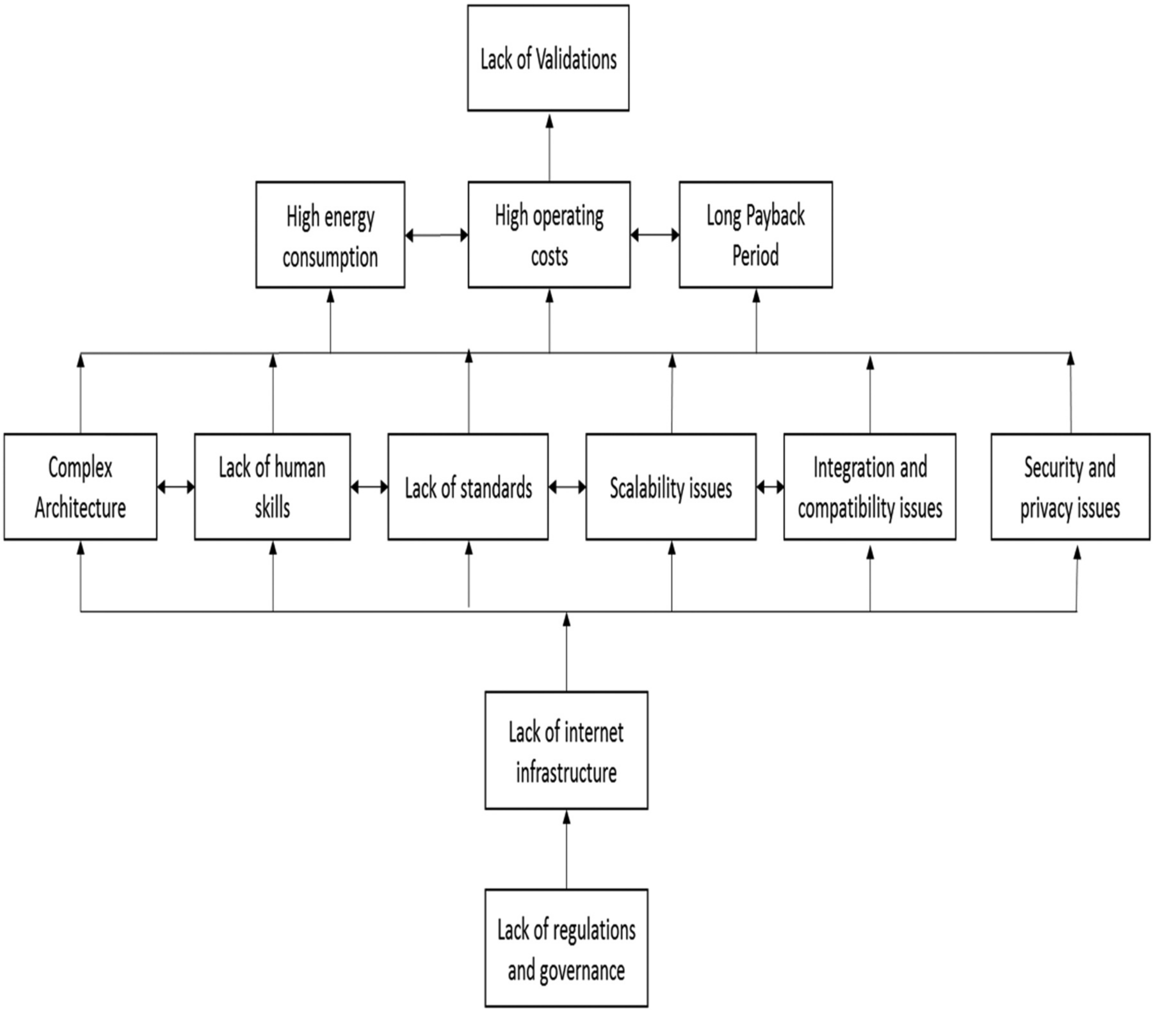

Fig. 2. Digraph depicting the relationship between the IoT adoption barriers.

dependence power and meager driving power. The dependence of these barriers on the other barriers indicates that the dependent barriers need support from all the other barriers to minimize its effect on the IoT implementation in the retail industry. These barriers are considered as critical barriers and need to be addressed by the practitioners on high priority.

The IoTBs namely: complex architecture (IoTB 1), lack of human skills (IoTB 4), lack standards (IoTB 6), scalability issues (IoTB 10), integration and compatibility problems (IoTB 11), and security and privacy issues (IoTB 12) were differentiated into various cluster III (linkage barriers). This cluster has high dependence influence and high driving influence, therefore is highly sensitive. Any change in these

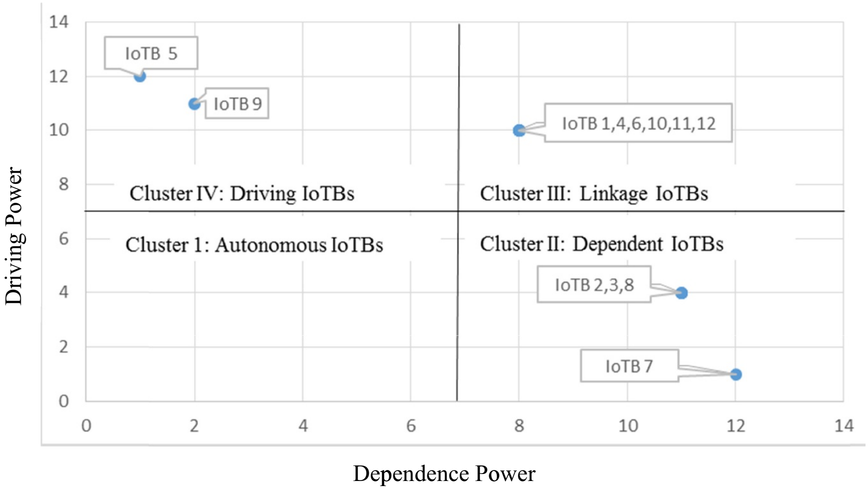

Fig. 3. MICMAC diagram for the IoT barriers.

Table 7
Direct influence matrix.

IoTB's	IoTB1	IoTB2	IoTB3	IoTB4	IoTB5	IoTB6	IoTB7	IoTB8	IoTB9	IoTB10	IoTB11	IoTB12
IoTB1	0	2	2	0	0	0	3	2	0	3	3	2
IoTB2	0	0	3	0	0	0	3	1	0	0	0	0
IoTB3	0	3	0	0	0	0	3	3	0	0	0	0
IoTB4	1	1	1	0	0	1	3	1	0	3	3	0
IoTB5	1	1	1	1	0	3	3	1	1	2	2	3
IoTB6	1	1	1	0	0	0	3	2	0	2	2	0
IoTB7	0	0	0	0	0	0	0	0	0	0	0	0
IoTB8	0	1	1	0	0	0	1	0	0	0	0	0
IoTB9	1	3	3	0	0	1	3	1	0	3	3	3
IoTB10	1	1	3	0	0	1	3	3	0	0	2	1
IoTB11	3	1	3	0	0	1	3	3	0	3	0	3
IoTB12	3	1	2	2	0	1	3	1	0	3	1	0

IoTB1: Complex architecture, IoTB2: High energy consumptions, IoTB3: High operating costs, IoTB4: Lack of human skills, IoTB5: Lack of regulations and governance, IoTB6: Lack of standards, IoTB7: Lack of validations, IoTB8: Long payback period, IoTB9: Lack of internet infrastructure, IoTB10: Scalability issues, IoTB11: Integration and compatibility issues, IoTB12: Security and privacy issues.

IoTBs will affect the other IoTBsat different levels and also have feedback on itself. The identified IoTBs in this cluster is contemplated to be highly volatile, impeding the execution of IoT in retail supply chains.

Cluster IV (driving barriers) have low dependence power and high driving power. This cluster includes the IoTBs, poor internet infrastructure (IoTB9) and lack of regulations and governance (IoTB5). The retail supply chain practitioners should address these IoTBs more carefully and consider them as the primary IoTBs. Any changes in the IoTBs in this cluster will have an impact on all the other IoTBs at all the different hierarchical levels.

5.3. Limitations of ISM

Even though the above findings revealed some interesting relationships between the selected IoTBs, the use of ISM confines us to draw interpretations based on the specific relationships between the IoTBs. ISM provides us with hierarchical relationships but fails to quantify the influence of IoTBs on each other. In the ISM methodology, the experts have denoted the relationship between two IOTBs using binary numbers (0 or 1). 0 is used for no relationship between the IOTBs whereas 1 signifies existence of the relationship. However, the relationship between these IOTBs cannot always be equal. Some relations may be strong, some may be very strong, and some relations may be better (Gartner, 2016). It is entirely possible that because of this limitation the ISM methodology is unable to provide us with explicit hierarchical relationships between the IoTBs. To overcome this drawback of ISM, the second stage of our analysis incorporated the DEMATEL methodology to identify the influential and active IoTBs. Compared to ISM, DEMATEL prioritizes the selected factors measuring their interactive effects on a quantitative basis. ISM provides details on the interactions between the selected factors in the form of a dependence structure (Safdari Ranjbar et al., 2014). The SSIM matrix was used as the input to perform the DEMATEL analysis.

5.4. DEMATEL model

The results of the ISM methodology shows the existence of interdependency between the IoTBs, but the degree of their dependencies are unknown. DEMATEL helps us to draw some valuable implications from the degree of influences shown in Table 10 and the diagraph from Fig. 4. The D + R and D-R values exemplify the cause and effect group factors respectively. For understanding the critical IoTBs, we should give high prominence to the causal factors with higher D + R values. This implies that cause group factors are independent and the effect group factors are easily driven by them (Hori and Shimizu, 1999).

From Table 10, the importance of the seven criteria can be prioritized using (D + R) values as IOTB11 > IOTB7 > IOTB12 > IOTB1 > IOTB3 > IoTB8 > IoT9 and so on. The integration and compatibility issues (IoTB11) is the most important criteria with a value of 2.88, followed by lack of validations (IoTB7) with a value of 2.76. The scalability issue(IoTB10) is identified as the least important criterion with a value of 1.19. The (D-R) values in Table 10, reveals the IoTBs namely; lack of regulations and governance (IoTB5), poor internet connectivity (IoTB9), lack of human skills (IoTB4), integration and compatibility issues (IoTB11), complex architecture (IoTB1), high energy consumption (IoTB2), lack of standards (IoTB6), and security and privacy issues (IoTB12) as net causes whereas, the IoTBs namely; high operating costs (IoTB3); lack of validations (IoTB7), long payback

Table 8
Normalized direct influence matrix.

IoTB's	IoTB1	IoTB2	IoTB3	IoTB4	IoTB5	IoTB6	IoTB7	IoTB8	IoTB9	IoTB10	IoTB11	IoTB12
IoTB1	0	0.095	0.095	0	0	0	0.143	0.095	0	0.143	0.143	0.095
IoTB2	0	0	0.143	0	0	0	0.143	0.048	0	0	0	0
IoTB3	0	0.143	0	0	0	0	0.143	0.143	0	0	0	0
IoTB4	0.048	0.048	0.048	0	0	0.048	0.143	0.048	0	0.143	0.143	0
IoTB5	0.048	0.048	0.048	0.048	0	0.143	0.143	0.048	0.048	0.095	0.095	0.143
IoTB6	0.048	0.048	0.048	0	0	0	0.143	0.095	0	0.095	0.095	0
IoTB7	0	0	0	0	0	0	0	0	0	0	0	0
IoTB8	0	0.048	0.048	0	0	0	0.048	0	0	0	0	0
IoTB9	0.048	0.143	0.143	0	0	0.048	0.143	0.048	0	0.143	0.143	0.143
IoTB10	0.048	0.048	0.143	0	0	0.048	0.143	0.143	0	0	0.095	0.048
IoTB11	0.143	0.048	0.143	0	0	0.048	0.143	0.143	0	0.143	0	0.143
IoTB12	0.143	0.048	0.095	0.095	0	0.048	0.143	0.048	0	0.143	0.048	0

IoTB1: Complex architecture, IoTB2: High energy consumptions, IoTB3: High operating costs, IoTB4: Lack of human skills, IoTB5: Lack of regulations and governance, IoTB6: Lack of standards, IoTB7: Lack of validations, IoTB8: Long payback period, IoTB9: Lack of internet infrastructure, IoTB10: Scalability issues, IoTB11: Integration and compatibility issues, IoTB12: Security and privacy issues.

Table 9
Total influence matrix.

IoTB values	IoTB1	IoTB2	IoTB3	IoTB4	IoTB5	IoTB6	IoTB7	IoTB8	IoTB9	IoTB10	IoTB11	IoTB1	Row Total (D-values)
IoTB1	0.06	0.17	0.20	0.01	0.00	0.03	0.29	0.20	0.00	0.20	0.18	0.14	1.47
IoTB2	0.00	0.02	0.15	0.00	0.00	0.00	0.17	0.07	0.00	0.00	0.00	0.00	0.42
IoTB3	0.00	0.15	0.03	0.00	0.00	0.00	0.18	0.15	0.00	0.00	0.00	0.00	0.51
IoTB4	0.09	0.11	0.14	0.00	0.00	0.07	0.27	0.14	0.00	0.20	0.18	0.04	1.25
IoTB5	0.12	0.14	0.18	0.07	0.00	0.18	0.34	0.18	0.05	0.20	0.17	0.20	1.81
IoTB6	0.08	0.09	0.12	0.00	0.00	0.01	0.23	0.16	0.00	0.13	0.12	0.03	0.98
IoTB7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IoTB8	0.00	0.06	0.06	0.00	0.00	0.00	0.06	0.01	0.00	0.00	0.00	0.00	0.19
IoTB9	0.12	0.24	0.28	0.02	0.00	0.08	0.35	0.19	0.00	0.23	0.20	0.19	1.89
IoTB10	0.08	0.11	0.21	0.01	0.00	0.06	0.26	0.22	0.00	0.05	0.12	0.07	1.19
IoTB11	0.19	0.14	0.26	0.02	0.00	0.07	0.32	0.26	0.00	0.21	0.07	0.18	1.72
IoTB12	0.18	0.13	0.20	0.10	0.00	0.07	0.30	0.16	0.00	0.21	0.12	0.04	1.52
Column Total (R values)	0.93	1.36	1.82	0.23	0.00	0.56	2.76	1.75	0.05	1.43	1.17	0.90	12.94

Table 10
Degree of influences.

IoTB's	Row Total (D)	Column Total (R)	D + R Values	D-R Values
IoTB1	1.47	0.93	2.40	0.55
IoTB2	0.42	1.36	1.77	0.42
IoTB3	0.51	1.82	2.33	− 1.30
IoTB4	1.25	0.23	1.48	1.02
IoTB5	1.81	0.00	1.81	1.81
IoTB6	0.98	0.56	1.54	0.42
IoTB7	0.00	2.76	2.76	− 2.76
IoTB8	0.19	1.75	1.94	− 1.56
IoTB9	1.89	0.05	1.94	1.84
IoTB10	1.19	1.43	1.19	− 0.24
IoTB11	1.72	1.17	2.88	0.55
IoTB12	1.52	0.90	2.42	0.61

period (IoTB8) and scalability issues (IoTB10) were the net receivers.

Table 9 shows the direct and indirect influences of the twelve criteria. A threshold value of 0.10 was computed derived on the average of elements in total relation matrix. This threshold value was used to depict the influence of IoTB graphically, as presented in Fig. 4. More specifically, the Fig. 4 exhibits that lack of regulations and governance (IoTB5), lack of human skills (IoTB4), and poor internet infrastructure (IoTB9), affects all the other IoTBs, but are not affected by other barriers. It is also observed that the barrier, lack of standards is directly influenced by the lack of regulations and governance (IoTB5) and not by any other barrier (Wu et al., 2010). This implies that the barriers, lack of government regulations, poor internet infrastructure and lack of human skills are important causes to be managed. All the three causes (IoTB5, IoTB9, and IoTB4) have the higher driving capability on the entire framework. This indicates that its improvement may lead to the development of the whole structure. Further, lack of validations(IoTB7) and long payback period (IoTB8) does not affect any other IoTB. However, they are influenced by all the other barriers.

5.5. Managerial implications

The physical food retail companies are in search of different sustainability programs to compete with the growing pressure posed by online food retailers. The various sustainability initiatives range from procurement and packaging to product development and innovation. One of the emerging technology initiatives is the adoption of IoT by

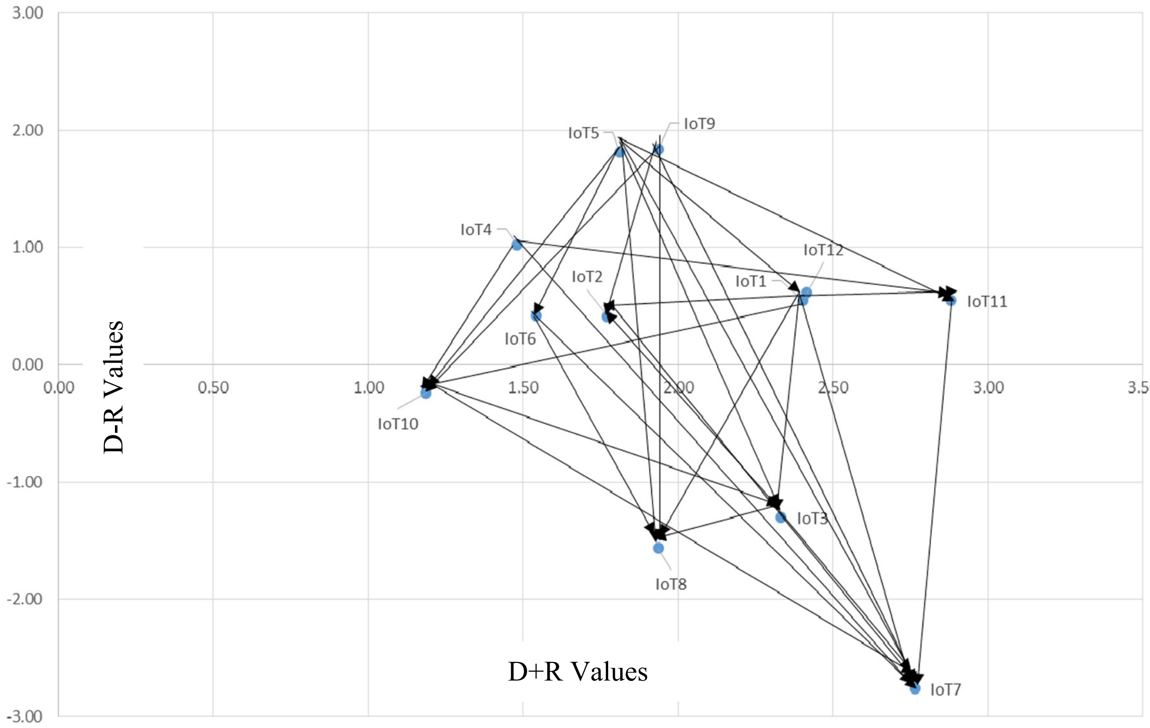

Fig. 4. Diagraph showing the influential relationship between the barriers.

these retail companies. However, these initiatives require an investment of resources in the form of financial capital, technology and human resources (Nadella, 2016). Embracing the technologies like IoT helps the organizations to understand more about their business, not only of their customers but also about their supply chain partners. In the future, the data-centric retail business will be leading the markets pushing the others who don't adopt these technologies out of business (Beecham Research, 2016). The findings identify the lack of validations of IoT in the retail food companies as a significant reason for lack of IoT adoption. This implies that successful validations are required to happen in the retail industry, and it is only possible when the practitioners are convinced about the benefits and improved profits IoT brings to the business. Presently, the reasons for lack of validations are perceived to be the high operating and implementation costs of IoT. The IoT implementation consultants are required to prepare case studies on successful deployments of IoT in retail food industries demonstrating the improvement in productivity and profitability. A good IT infrastructure that includes robust internet connectivity not only at the stores but also having the capability of connecting the suppliers and customers at various levels of SC is essential to the adoption of IoT in the retail food business. Usually, the IT infrastructure is not able to keep pace with the rapidly increasing and changing demands of markets. Therefore, it is implied that for the future development of IoT in food retail, the retail food companies should have a robust IT strategy. The other aspect of IT strategy should be to decide on the level of big data capabilities the company should possess. The retail companies need to have a well-defined plan on how to develop the analytical capability (Carolan, 2018). The level of IT and big data analytical capabilities will also decide on the requirement of the appropriate human skill sets.

Further, many applications runs on IoT, such as blockchain and RFID trackers that need to comply with the existing rules and regulations of the country. These new applications offer high-value benefits such as product traceability which is very critical in a food supply chain. However, India presently lacks regulations and governance regarding the transparency of information, data sharing security, about the type of data to be shared and kind of technology that should be used. In other countries, the retail transformation took place in some decades whereas, in India, it happened in a short span of time and with a varied type of retail formats. Policies such as tax breaks, infra-structural support, support to reach maximum customers with a multiple numbers of digital retail/ electronic transactions can be facilitated to small food retailers to compete with large retailers (Sebastian and Gupta, 2018). The physical stores should also be motivated to access e-commerce facilities by associating with retail aggregators and reaching maximum customers with less cost. More such initiatives should be encouraged by the Government, acting as incentives for implementing IoT in the retail food business (Sebastian and Gupta, 2018). One of the significant findings of the study was that the barrier, lack of standards is directly influenced by the lack of regulations and governance (IoTB5) and not by any other barrier. This implies that once the practitioners in the food retail business should start adopting the GS1 standards for data standardization and information sharing across the various supply chain partners. The information shared between the suppliers of the food products and the retailers can be utilized by the food retailers for the improvements in their business processes and it is necessary that the information is complete, accurate, and consistent. GS1 assures that the information satisfies all these requirements maintaining the information quality. The GS1 has validation tools that uses logical control mechanisms, ensuring accurate and consistent data as per the international standards. The lack of seamless integration possibilities as one of the barriers of IoT adoption implies that the system integrators should aim to design architectures to achieve seamless integration. GS1 and HACCP can play a critical role in providing seamless integration by use of uniform data format. This will enable the IoT applications to manage versatile data with more dominant features (Tseng et al., 2015, 2016).

6. Conclusions

IoT applications in the food retail business is expected to facilitate the acquisition of new capabilities providing the practitioners with new insights on value proposition and creation, helping them to strengthen their customer relations and provide personalized retail experience for them. This is one of the preliminary studies that identifies and analyze twelve IOT adoption barriers and categorize them based on their dependence and driving power using ISM methodology. The DEMATEL further classifies them as cause and receiver barriers. The findings of the study suggests that the practitioners from retail supply chains should pay high attention to three main leading causes namely: lack of regulations and governance (IoTB5), lack of internet infrastructure (IoTB9) and lack of human skills (IoTB4), rather than focusing on the significant receivers such as lack of validations (IoTB7) and long payback period (IoTB8). The findings of the study implies that the retail organizations are expecting government interventions in development of policies and regulations, for the use and operation of devices, data storage, and usage. The food retail businesses are also concerned with the lack of human skills having good data analytics capability to handle the data enabled systems with ease. A food retail supply chain consists of various stakeholders, and for successful implementation of IoT, all these stakeholders have to be brought on a common platform with a common objective. This is seen as a challenging task and therefore is acting as a significant hurdle as most of these stakeholders presently have their legacy systems and procedures based on different platforms making the supply chain integration highly challenging. The outcome of this paper provides essential guidelines for practitioners and consultants in the food retail industry. The practitioners are required to focus on the identified barriers for IoT adoption carefully. Once the significant cause IOT adoption barriers are resolved, the practitioners should frame strategies for reducing its effects for IoT adoption. Like any other studies, this study also has few limitations. The weights for the ISM and DEMATEL model development were obtained based on judgments of the experts drawn from the retail supply chain, technology, and computer science industry. It is likely that the final results of the study might have been affected the subject expert bias, evaluating the IOTBs. An empirical survey across different types of retail formats may be conducted in future to gain more insights on this sector on IoT adoption. Statistical validations of the identified relationships between the IoTBs may be tested by using structural equation modeling (SEM).

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