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Modelling and Analysis of key Enablers of Digital Transformation in Food SMEs using ISM and MICMAC Approach

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ABSTRACT

The food business in India is the backbone of the country, meeting the fundamental human need of food for a large portion of the country's population while also exporting it to other countries. Small and Medium-sized enterprises (SME's) account for the major share of total food production, even though they lack the necessary technological infrastructure and operating standards. Due to COVID-19 crisis, the food sector has been obliged to resolve and upgrade to the new laws tralatitious by the government, which has significantly stimulated the long-awaited digital transformation of food SMEs in India. The purpose of this study is to identify and analyse the major enablers of digital transformation in food SMEs. The Interpretive Structural Modelling (ISM) methodology has been used to categorize the identified enablers of digital transformation, which further helps in identifying the most proactive enabler and assess the integration of other enablers in the technological paradigm.

Keywords: Digital Transformation, Enablers, Industry 4.0, Food SMEs, ISM, MICMAC.

1. INTRODUCTION

Liberalization of Foreign Direct Investment (FDI) policies and reforming of macro-economic parameters have resulted in up-scaling the growth of production, logistics, processing, manufacturing and service sector of food and beverage related enterprises. This is achieved by the inculcation of international procedures, standards and technical know-how related to the processes and business tactics implemented, along with the technological advancement and proactive participation of the enterprise’s management in bringing about the paradigm shift in the highly potential sector of India. According to Forbes statistics study, food and beverage industry stands tall with being the fifth largest

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sector for manufacturing. The lasts consensus shows that the financial year 18-19 has already been big in investing in this sector, with around 263 million dollars invested so far, as stated by Department of Industrial Policy and Promotion (DIPP). A study from The Economic Times points out the potential of Indian food processing sector to influence around 33 billion US dollars in the form of investments by the year 2024 (The Economic Times, 2019). Adding to this, the nation's food and retail market is subjected to bloom with a whooping investment of around 482 billion US dollars by the year 2020, which is almost 190% increment from the investment in the year 2015 (IBEF, 2019). This is also backed up by a collaborative study by Assocham and Grant Thornton, being an Indian industry body and professional service firm based in Chicago respectively, which emphasizes on the future prospect of big investments in technology related to food processing and manufacturing, labor skill development and increased equipment in the coming 10 years. This results in more job generation and higher processing of food to meet the demand of the growing need of the nation to feed the progressively multiplying population. Apart from being a developing nation and feeding its own population, India leads in foreign exports of products and is a production hub for various processed foods in countries like South Asia, Africa, USA and Middle East. Due to the global market for Indian food products, there is a constant need for a policy to standardize the production quality to meet the global standards and help increase Indian food export business.

The food industry in India has been running with the traditional methodologies for ages, especially SME's as they are not proactive in enabling latest technologies and techniques due to the insurgence of cost, skilled labor and new operating procedures for the industry. This has dramatically changed upon the spread of the COVID-19 pandemic across the globe. The geographical domination of the virus has handicapped the traditional ways of running industries and have forced the stakeholders to innovate the ways they operate the industry. Recent advances in the operations of industry have finally started the mass drive of revolutionizing the enterprises towards a more efficient and self-operational industrial setup. With the limitations in employing labor on shop floors and in offices, the need to set up technologies that can replace and upgrade the work environment to a safer norm while following social distancing has become the need of the hour. To minimize the risk of the spread of virus, the new regulations restrict the workforce that can work in close proximity and hence, innovations to manage the existing technologies came to existence (Agrawal et al. 2020).

The global pandemic has forced the industrial revolution in food industries and hence, innovations and new technologies are being seen in the enterprises that can keep pace with the new trend in the industrial sector. The existing bottlenecks in the food industry are being forced to resolve and upgrade to the new regulations laid down by the government amid the COVID-19 crisis and this has substantially propagated the long-awaited digital transformation of food SMEs in India. The new world order is beneficial to the digitalization of the industry and this research is focused to identify the enablers involved with the transformation of enterprises in the food industry in India. On the basis

of the above issues and limitations in studies we have set up the following research questions are formed:

RQ-1: What are the key enablers of Digital Transformation of Food SMEs in India.

RQ-2: Analysis of the key enablers of Digital Transformation of Food SMEs in India using ISM and MICMAC Approach.

To answer the above-mentioned research questions, initially key enablers of digital transformation in Indian food SMEs are identified. The Interpretive Structural Modelling (ISM) methodology is used to differentiate the various levels of the identified enablers that could give a clear prospect of the parameters and their degree of influence in affecting the industrial digital transformation.

2. LITERATURE REVIEW

In recent years, the food sector in India has been a new focus for researchers because of the impact it has on the economy and people of the country. In order to make the most of the enabling parameters for the digital transformation, it is critical that the industry's parameters that affect a favorable outcome be identified. Research papers, conference proceedings, news articles and general statistical studies published by industry experts are reviewed extensively to get a sense of the various influencing parameters and then used to build an inter-relationship with the level of effect the parameters have on the possibility of digital transformation in Indian food SME's. After referring to a total of 129 articles from research journals, conference proceedings and published reports, 34 papers were shortlisted along with a few online published articles on the basis of the criteria associated with our research prospect and the relevant content incorporated on par with the core crux of our research methodology and help us with a constructive result and discussion panel. These papers give a detailed introspection about the various parameters that positively influence and accelerate the enterprise's aim to transform digitally and upon careful consideration and guidance from many research enthusiasts, there parameters are converted to a generalized enabler, which can further be studied to identify their importance and level of effect on Indian food SME's.

Fritz and Schiefer (2008) talks about automation of conventional information transfer methods into a highly dynamic system based on internet and cloud computing that could monitor and manage information on competitive and local level by developing a framework for the same. Gardino et al. (2009) suggests a framework for traceability system evaluation in agri-food industry and the implementation of automation by utilizing a RFID based traceability system and show the analysis and comparison of the results to the methodology of the traditional traceability systems. Ostrouh and Kuftinova (2012) study a network for the logistics of production transport system and develop optimization algorithms that could plan and manage the transport vehicles by minimizing transport expenditure and maximize the quality of the services rendered. Ping-zeng et al. (2009) suggests the implementation of Fuzzy Control System (FCS) for the improvement of the existing intelligent

monitoring and control system so that a higher level of automation and improvement on the stored food quality can be achieved. Trebar et al. (2011) talks about two examples of how RFID tags can be implemented in SME's for the farmed fish traceability by developing a system for the same. Fu et al. (2019) discusses about the decision to invest in a three-tier fresh food supply chain traceability using RFID tags by linking retailer, supplier and manufacturer and to provide managers with a productive insight regarding the investment decision. KatarzynaKosior (2018) discusses about digitalization of agri-food sector and the issues and enablers associated with the implementation of digital transformation in context with traceability, IoT integration and cloud computing. Bader and Rahimifard (2018) explores the possibility of automation of food manufacturing by introducing industrial robots and study the challenges associated to it which bottleneck the industrial implementation of robots to automate the sector. Desai et al. (2017) proposes a prototype model which can integrate IoT and e-commerce by monitoring the inventory level of groceries at home and in supermarkets so as to create an efficient reordering and tracking of the inventory. Khana et al. (2018) discusses about the potential of industrial robots and how cyber-physical systems can promote and effectively influence the optimal integration of robots in food manufacturing, thus reducing human errors and increase productivity. Loo et al. (2015) aims to understand the issues and challenges associated with product distribution from rural SME's to the market and identify crucial parameters that can be corrected or optimized to minimize this hindrance and strengthen the supply chain. Iqbal et al. (2017) limelight the various prospects of industrial robots in food sector and studies the kinematics, maintenance, credibility, quality and efficiency of robots to conclude how industrial robots have new opportunities in the food service sector.

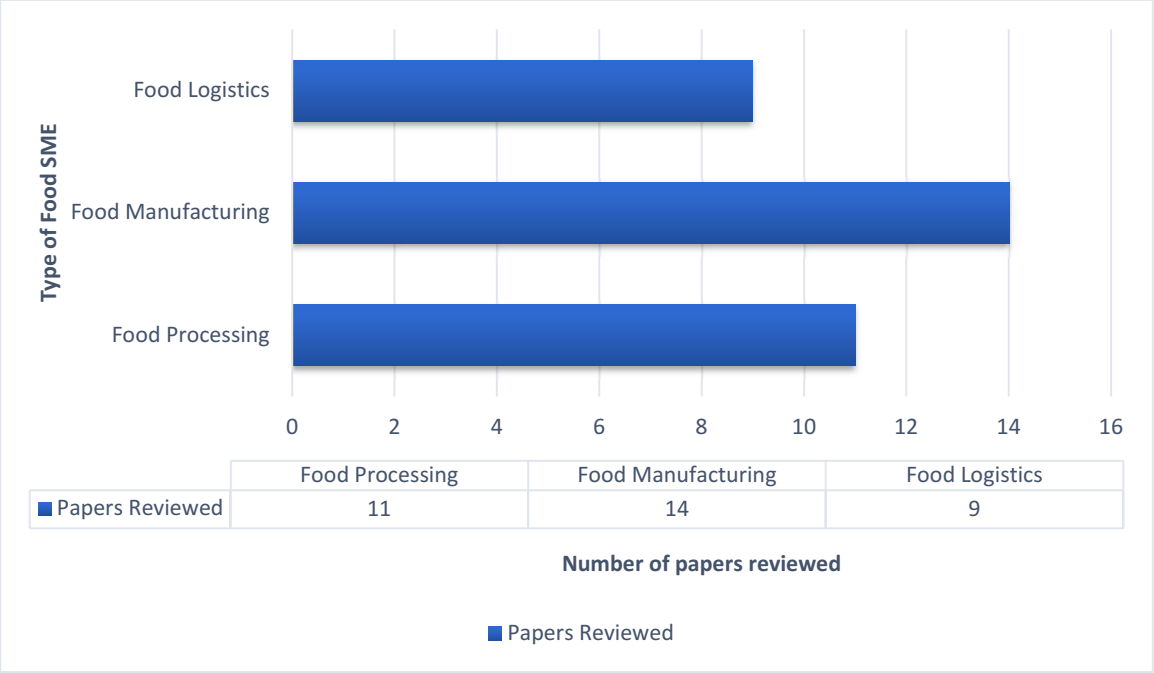

Figure 1. Types of Food SME's

RQ-1: What are the key enablers of Digital Transformation of Food SMEs in India.

As the global pandemic of COVID-19 has been in existence since the year 2020, researchers have been active in identifying the difficulties and solutions that can be implemented swiftly to assist in the transformation of the food industry to a digital environment. Schiliro (2020) explains how digital globalization has evolved into a new form of globalization and how it has influenced businesses and industries to adopt new technologies to make their jobs easier, whereas leadership and stakeholder involvement have been identified as important criteria for active transformation, according to the author. Nicola et al. (2020) discusses the socio-economical effects of coronavirus and the surge in the consumption of food products due to hoarding and panic-buying and suggests managerial implications and sustainable business models that can promote digital transformation. Manivannan et al. (2020) highlights the surge in the food logistics model due to COVID-19 pandemic in India and displays the transformation in the client delivery methods that have been digitalized for easy access by consumers. He signifies the company's vision to slowly expand the digital transformation processes in wake of coronavirus and lead the industry towards newer ways to transform food industry. Galanakis (2020) highlights the importance of food industry in the economy and the necessity to check and implement new technologies to convert food chain into a sustainable model and provide quality check to disrupt the chances of coronavirus transmission via food products. The transformation towards Industry 4.0 can help in the reduction of wastage of food and safer measures to continually quality check the food products manufactured and processed in the industry.

The research paper focuses on three type of food SME's, namely Food Processing, Food Manufacturing and Food Logistics. The various paper reviewed above are based on these three types of SME's and help generate a general consensus regarding the level of digital transformation, the enablers that influence the transformation and the critical factors that makes digital transformation a success. Figure 1 shows the reviewed paper distribution between the three types of classification. It is noticed that food manufacturing plays a crucial role in the talks for digital transformation, followed by food processing and then fppr logistics. This bifurcation helps develop an idea of the industry that has been the centre of focus of other researchers in the prospect of digital transformation of food SME's. To answer the RQ-1, the various reference sources reviewed, a total of 12 enablers are identified that have strong influence on the digital transformation in food SME's. all the enablers are categorized under three primary sections, namely Technological, Financial and Organizational & Political. The same is summarized in the Table 1 shown below.

Table 1. Description of various enablers of food industries that influence digital transformation

S.No.	Type Of Enabler	Enabler	DESCRIPTION	SOURCE REFERENCE
E1	Technological	Automation	Implementation of newer technologies that can help achieve better productivity, less fatigue and minimization of human errors.	Jałmużna et al. (2018); Ferrero at al. (2018); Fritz and Schiefer (2002); Gandino et al. (2009); Kopishynskaet al.(2018); Ostrouh and Kuftinova (2012); Harun et al.(2018); Trebar et al. (2013); Walker and Barnes (2005); Lefebvre et al. (2015); Baderand Rahimifard (2018); Besnea (2018); Iqbal et al. (2017); Khan et al. (2018); Galanakis (2020).
E2		Cloud Computing	Utilisation of internet to create a network of information transfer, storage and processing which could help synchronise the information flow and retrieval in the production capacity.	Cai et al. (2015); Fritz and Schiefer (2002);Kopishynska et al.(2018); Ndou et al. (2010); Kosior (2018).
E3		Sensor Aided Cyber Physical Systems (CPS)	Inculcation of sensors to physical systems so that the data can be collected without human intervention and thus, reducing the chances of human actuated data inconsistency.	Jałmużna et al. (2018); Chen (2017); Ferrero et al. (2018); Gandino et al. (2009); Harun et al.(2018); Baderand Rahimifard (2018); Iqbal et al. (2017); Khan et al. (2018); Prathipati et al. (2021).
E4		Information Technology (IT)	Intervention of technology to regulate the flow of information as well as creating a network for simplified data transfer among various sources.	Kopishynskaet al.(2018); Ostrouh and Kuftinova (2012); Walker and Barnes (2005); Ushada et al. (2017); Manivannan et al. (2020).
E5		Internet Of Things (IoT)	Network of technology-based drivers that can control data sharing and help in remotely controlling the connected devices via internet.	Cai et al. (2015); Ferrero et al. (2018); Kopishynska et al.(2018); Ndou et al. (2010); Harun et al.(2018); Trebar et al. (2013); Walker and Barnes (2005); Kosior (2018); Baderand Rahimifard (2018); Sharma et al. (2022); Besnea(2018); Desai et al. (2017); Iqbal et al. (2017); Krishnan et. Al. (2021).
E6		Radio Frequency Identification (Rfid)	Traceability centred utility device that helps in data transfer and collection for inventory management and production processes.	Chen (2017); Ferrero et al. (2018); Gandino et al. (2009); Trebar et al. (2013); Fu et al. (2010); Desai et al. (2017).
E7	Financial	Investment	Providing financial aid such as implementation cost for new technology or upgrading existing technology, increase production capacity or to fund human resource.	Chen (2017); Ferrero et al. (2018);); Gandino et al. (2009); Lavelli (2013); Lefebvre et al. (2015); Besnea et al. (2018); Nicola et al. (2020); Galanakis (2020).

E8		Stakeholder(S)	Proactiveness in regard to the industry's requirement and organisational managerial aspects that require involvement of expertise for decision making.	Lavelli (2013); Lefebvre et al. (2015); Iqbal et al. (2017); Khan et al. (2018);Schiliro (2020); Galanakis (2020).
E9	Organisational And Political	Supply Chain Management (SCM)	Robust network of product logistics from vendor to customer which can help the overall production facility.	Ndou et al. (2010); Ostrouhand Kuftinova (2010); Walker and Barnes (2005); Bader and Rahimifard (2018); Desai et al. (2017); Manivannan et al. (2020).
E10		Information Management	Implementation of management tactics to collect, store and retrieve information associated to the firm.	Fritz and Schiefer (2002); Koszela et al. (2015); Harun et al. (2018); Fu et al. (2010); Desai et al. (2017); Van der Loo et al. (2015); Schiliro (2020); Manivannan et al. (2020)
E11		Policy and Regulations	Adhering to the governmental policies and organisational regulations in favour of the benefit of the enterprise while maintaining the ethical norms.	Jałmużna et al. (2018); Ferrero et al. (2018); Kopishynska et al. (2018); Lavelli (2013); Goue et al. (2017); Bader and Rahimifard (2018); Khan et al. (2018); Ushada (2017); Manivannan et al. (2020); Dangayach et al. (2020).
E12		Training	Development of employees to undertake dynamic changes in management style, technology or production processes.	Kopishynska et al.(2018); Dangayach et al. (2022). Vignali et al. (2017); Nicola et al. (2020).

The above table displays the 12 prominent enablers that aid digital transformation in food SME's, maximization of which can help propagate the transformation process at a higher pace. These enablers may or may not be inter-dependent and can influence the transformation process in different ways. To study the dynamic relation of the enablers and its influence on the digital transformation of food industry, the application of ISM methodology is carried out which can show the dependencies between various enablers and high driving enablers that are the most influencing factor for the transformation. ISM also help develop a contextual relationship which can be seen with a level partitioning of the various enablers and hence, help determine the driving enablers and depending enablers through MICMAC analysis.

Considering the various researches that have taken plane in the last 20 years in the field of food industries, only limited research showcases the prospect of digital transformation and the possible methods to effectively achieve them in the industry. The literature review is broadly spread across the majority of the countries in the world and due to the limited presence of research related to digital transformation in food SME's in India, the research area was selected that could provide new and relevant information that could help the researchers working in the same field of expertise. Encompassing the need to develop a research study to highlight the digital transformation priorities, identification of enablers was taken as the primary motive of the research study that can add to the existing research studies conducted in this industry. This is achieved after collection of various papers

related to the finalized research topic and detailed study of the content to identify the enabling factors that govern the digital transformation. It is evident that different enterprise has their own set of enablers and that the enablers are not standard and vary with different enterprises, a panel of industry experts and research enthusiasts was approached that could help identify the common parameters to finalize a final list of enablers that do justice to the majority of the enterprise in the respected sector.

RQ-2: Analysis of the key enablers of Digital Transformation of Food SMEs in India using ISM and MICMAC Approach.

After carefully reading and studying the aforementioned research articles, it is clear that the digitization process is influenced by several variables. Enabling factors that may summarize significant characteristics in food processing, manufacturing, and logistics SME's must be identified so that they can be prioritized to have a framework that is self-explanatory in terms of crucial enablers that drive the digital transformation. To give the answer of RQ2, the interpretive structural modelling (ISM) approach has been used. Through ISM methodology and validation of that theory by way of a case study, the research aims at discovering answers and generating theories that relate the data. In order to establish the interdependency between enablers in the system and the hierarchical level partitions, MICMAC analysis was utilized to identify them. Verified facilitators' interpretation of the ISM results in terms of their practical implications and future prospects.

3. METHODOLOGY

The approach consists of three crucial words, namely Interpretive, Structural and Modeling. The methodology is interpretive with its judgement due to the discussion with various sources that are capable of providing input towards the identification and selection of the parameters. The word structural denotes the formation of a relationship between the individual parameters identified. The modeling phase is a direct notation for the construction of directed graph or diagraph which showcases the framework of the model and also helps prioritize the parameters in order of their influence Sushil (2018). Following a thorough assessment of the literature, twelve key enables and their associated criteria for deploying a tracking and tracing system in the digital transformation of food SME’s were identified. In order to get insight into these drivers and their implementation aspects, it is essential to have a systematic approach. There are a variety of approaches available for this purpose, including interpretive structural modelling (ISM), total interpretive structural modelling (TISM), DEMATEL, and AHP, among others. These include ISM and TISM, both of which highlight the structural link between the components but do not explain the strength of the association Jamwal et al. (2021). Interpretive Structural Modeling is a process of learning about elements that are directly or indirectly related in an interactive outlay which is structured into a visually detailed schematic model Attri et al. (2013). The model framework developed using ISM approach showcases the inter-relationship

between various parameters existing in a system and graphically implies the degree of influence it portrays on the identified cause of the research Kamble et al. (2018). It helps develop an insight into the research by providing the individual parameters with possible relationships amongst another parameters Singh et al. (2007). This collective understanding of the framework generated describes the level of effect the parameter has on the overall system and the degree of dependency a driving parameter has in a comprehensive structured model Patidar et al. (2017).

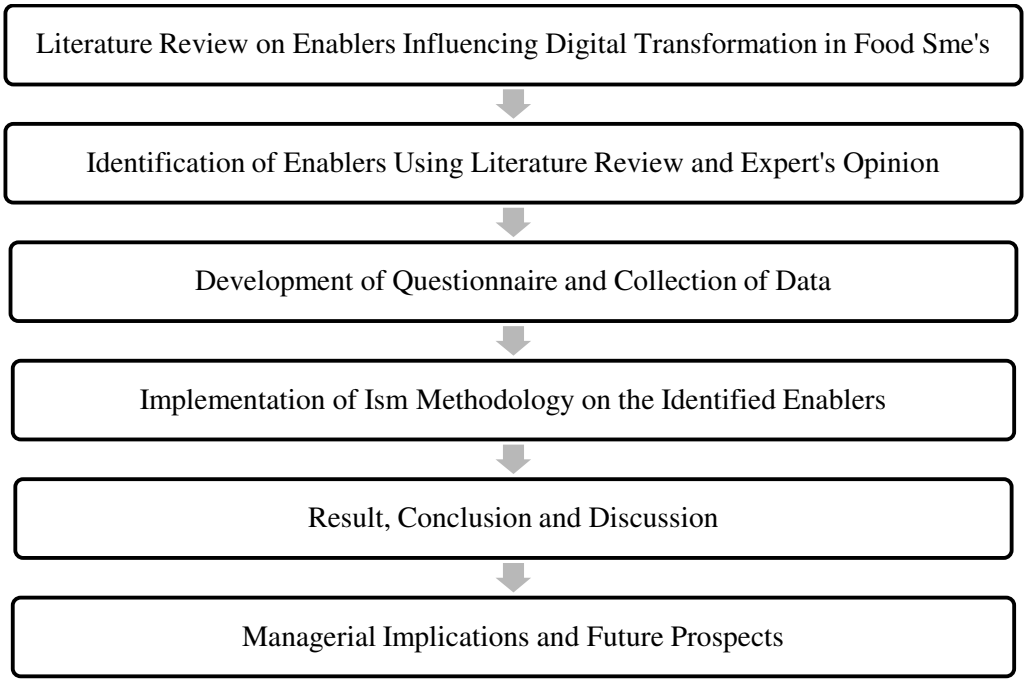

Figure 2. Flow chart to identify and prioritize the influential enablers of the digital transformation of food SME's

Figure 2 displays the chronological order in which the identification of enablers from the literature review takes place to the conclusive study which demonstrates the model framework for the prioritization of enablers using ISM approach. The identified enablers are subjected to review from industrial experts and research enthusiasts so that any possible modification can be inculcated before the application of ISM methodology on the enablers. The tool approach produces a result showing the contextual relationship between the enablers and level the partition that can showcase the degree of influence of the enablers at different hierarchy of the developed framework (Jamwal et al., 2020). This inter-relationship helps generate a constructive discussion regarding the obtained result which could help summarize the digital transformation priority of enablers of food SME's.

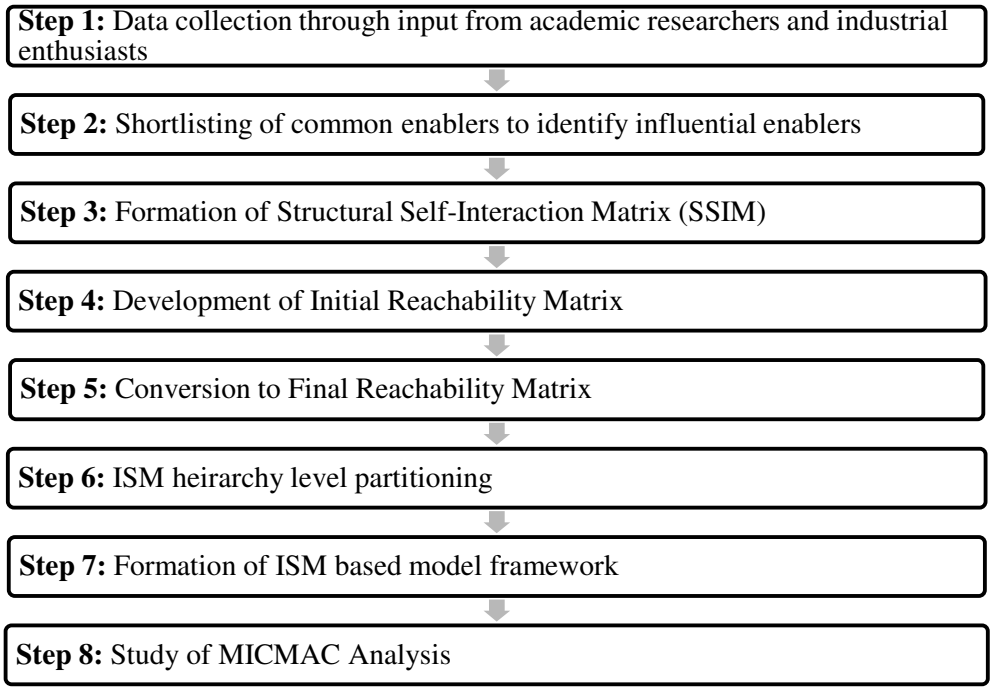

Figure 3. ISM methodology flow chart

The implementation of ISM methodology can be summarized into eight steps as shown in Figure 3 which when applied chronologically, results in a successful development of model framework and MICMAC analysis. The detailed procedure of the ISM approach is mentioned in the 8 steps stated below.

Step 1: Data collection through input from academic researchers and industrial enthusiasts

This step is a continuation from the last methodology where the common parameters were identified through literature review. These identified parameters are then subjected to expert's opinion so that the most influential factors could be narrowed down and possible corrections in the parameters could be initiated. This is done by conducting a pilot survey which could help identify the nature of the preliminary literature research to identify common enablers.

Step 2: Shortlisting of common enablers to identify influential enablers

After successful collection of the data input, the 17 identified common parameters were shortlisted to a total of 13 influential enablers that best describe the research motive. The shortlisting is carried out by collecting expert's opinion on the scale from 1 to 5 that describe the level of effect of the parameter and the collected result was sorted, keeping the threshold value to be above 3. All the responses from the expert's having the average value of 3 or above were taken for further consideration and those parameters were identified as influential enablers for digital transformation.

Step 3: Formation of Structural Self-Interaction Matrix (SSIM)

This step is expected to gather expert's opinion by brainstorming the identified enablers and their relationship with other enablers so that a contextual relationship of the total enablers could be

understood in detail. This insight regarding the parameters in play is then converted into a matrix where the identified relationships help fill the table which could help develop a more visual approach of the brainstormed enabler influences and relationships. A matrix of size equal to the number of enablers is constructed where the i_{th}element represents the element in row and j_{th}element represents the element in column. This way, the matrix consists of 144 vacancies which when filled based on the influence of enabler 'a' on the enabler 'b', would form into a detailed representation of the influence of an enabler to all other enablers in the system. The SSIM is then developed which can help establish a contextual relationship between various enablers. The direction of the brainstormed enabler-to-enabler relationship between enabler ***(i,j)***is denoted using four important symbols, expressed as:

- **V** – Enabler ***I*** will influence the enabler ***j***
- **A** – Enabler ***j*** will influence the enabler ***i***
- **X** – Enabler ***I*** and ***j*** will influence each other
- **O**– Enabler***I*** and ***j*** will not influence each other

Utilisation of the symbol system mentioned above, the SSIM is developed, thus describing comprehensively the inter-relationship of the various enablers with each other, as shown in Table 2.

Table 2. Structural Self-Interaction Matrix (SSIM)

Enablers/Parameters		**E12**	**E11**	**E10**	**E9**	**E8**	**E7**	**E6**	**E5**	**E4**	**E3**	**E2**	**E1**
Automation Systems	**E1**	A	A	A	A	A	A	V	X	O	X	V	-
Cloud Computing	**E2**	O	X	X	X	A	A	V	V	X	V	-	
Sensor Aided Cyber Physical Systems (CPS)	**E3**	X	X	X	A	A	A	X	X	X	-		
Internet of Things (IoT)	**E4**	V	V	X	X	O	A	X	X	-			
Radio Frequency Identification (RFID)	**E5**	A	X	X	X	A	A	X	-				
IT Infrastructure	**E6**	O	A	X	V	A	A	-					
Financial Support	**E7**	V	A	O	V	X	-						
Stakeholder(s) Involvement	**E8**	V	X	V	V	-							
Robust Supply Chain Management	**E9**	X	A	X	-								
Information Management	**E10**	A	X	-									
Regulations and Policies	**E11**	V	-										
Employee Training and Development	**E12**	-											

Step 4: Development of Initial Reachability Matrix

The reachability matrix comprises of two important phases in which the matrix is converted into binary form and then checked for transitivity. The first phase is an approach to convert and develop the generated SSIM into a binary attribute-oriented matrix as per the symbol substitution protocol which is bifurcated into four distinct rules with respect to the ***V***, ***A***, ***X*** and ***O*** symbols used. The rules explain us that:

- If the (***i,j)*** matrix cell in the SSIM is ***V,*** then the (***i,j)*** matrix cell in the reachability matrix is substituted with 1 and (***j,i)*** matrix cell is substituted with 0.
- If the (***i,j)*** matrix cell in the SSIM is ***A,*** then the (***i,j)*** matrix cell in the reachability matrix is substituted with 0 and (***j,i)*** matrix cell is substituted with 1.
- If the (***i,j)*** matrix cell in the SSIM is ***X,*** then the (***i,j)*** and (***j,i)*** matrix cell in the reachability matrix is substituted with 1.
- If the (***i,j)*** matrix cell in the SSIM is ***O,*** then the (***i,j)*** and (***j,i)*** matrix cell in the reachability matrix is substituted with 0.

Implementation of the rules mentioned above can help in the conversion of the SSIM into Initial Reachability Matrix, which is further shown in the Table 3 mentioned below.

Table 3. Initial Reachability Matrix

ENABLERS/PARAMETERS		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
Automation Systems	**E1**	1	0	1	0	1	1	0	0	0	0	0	0
Cloud Computing	**E2**	1	1	1	1	1	0	0	0	1	1	1	0
Sensor Aided Cyber Physical Systems (Cps)	***E3***	*1*	*0*	*1*	*1*	*1*	*1*	*0*	*0*	*0*	*1*	*1*	*1*
Internet of Things (Iot)	**E4**	0	1	1	1	1	1	0	0	1	1	1	1
Radio Frequency Identification (RFID)	**E5**	1	0	1	1	1	1	0	0	1	1	1	0
It Infrastructure	**E6**	0	1	1	1	1	1	0	0	1	1	0	0
Financial Support	**E7**	1	1	1	1	1	1	1	1	1	0	0	1
Stakeholder(s) Involvement	**E8**	1	1	1	0	1	1	1	1	1	1	1	1
Robust Supply Chain Management	**E9**	1	1	1	1	1	0	0	0	1	1	0	1
Information Management	**E10**	1	1	1	1	1	1	0	0	1	1	1	0
Regulations and Policies	**E11**	1	1	1	0	1	1	1	1	1	1	1	1
Employee Training and Development	**E12**	1	0	1	0	0	0	0	0	1	1	0	1

Step 5: Conversion to Final Reachability Matrix

The second phase of the development of reachability matrix is the introduction of transitivity check in the initial reachability matrix obtained from the table above. Transitivity is a basic assumption of ISM approach which follows a protocol that showcases the correlation between three random elements of the matrix generated. The rule of transitivity explains the assumption made that if there are three enablers selected at random and assumed as enabler ***A, B*** and ***C,*** then the relation between the enabler ***A*** and ***B,*** and the relation between the enabler ***B*** and ***C*** clearly demonstrate the affirmative relation between the enablers ***A*** and ***C.*** Application of transitivity check in the initial reachability matrix and reconsideration of the influences of the identified enablers, the transitive matrix cells are converted from 0 to 1 and thus, developing the final reachability matrix as shown in the Table 4 displayed below where the summation of the elements of the row projects the driver power of the enabler whereas the summation of the column projects the dependence power of the enabler.

Table 4. Final Reachability Matrix

ENABLERS/PARAMETERS		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	DRIVER POWER
AUTOMATION SYSTEMS	E1	1	0	1	1	1	1	0	0	0	0	1	0	6
CLOUD COMPUTING	E2	1	1	1	1	1	1	0	0	1	1	1	0	9
SENSOR AIDED CYBER PHYSICAL SYSTEMS (CPS)	E3	1	1	1	1	1	1	0	0	0	1	1	1	9
INTERNET OF THINGS (IOT)	E4	1	1	1	1	1	1	0	0	1	1	1	1	10
RADIO FREQUENCY IDENTIFICATION (RFID)	E5	1	0	1	1	1	1	0	0	1	1	1	0	8
IT INFRASTRUCTURE	E6	1	1	1	1	1	1	0	0	1	1	0	0	8
FINANCIAL SUPPORT	E7	1	1	1	1	1	1	1	1	1	0	1	1	11
STAKEHOLDER(S) INVOLVEMENT	E8	1	1	1	1	1	1	1	1	1	1	1	1	12
ROBUST SUPPLY CHAIN MANAGEMENT	E9	1	1	1	1	1	0	0	0	1	1	0	1	8
INFORMATION MANAGEMENT	E10	1	1	1	1	1	1	0	0	1	1	1	0	9
REGULATIONS AND POLICIES	E11	1	1	1	1	1	1	1	1	1	1	1	1	12
EMPLOYEE TRAINING AND DEVELOPMENT	E12	1	1	1	0	0	0	0	0	1	1	0	1	6
DEPENDENCE POWER		12	10	12	11	11	10	3	3	10	10	9	7	108

Step 6: ISM hierarchy level partitioning

This step involves the derivation of reachability and antecedent set from the final reachability matrix developed. The reachability set comprises of the enabler itself and the other enablers that are influenced by it whereas in the antecedent set, it comprises of the enabler itself and other enablers that influence it. After determining the reachability and antecedent set from the final reachability matrix, the intersection of both sets are identified and the enablers having exactly similar elements in the reachability set and the intersection set are awarded the top level in the ISM hierarchy and display the ability of the enabler to not influence any other enabler above its own level in the hierarchy framework developed. This step follows the iteration of the three sets identified and once a level partition is determined, the elements of the intersection set of the specific enabler is removed from the iteration so as to actuate the process for the next level of partitioning. The iterations are carried out till the point where all the enablers involved in the study are assigned a level partition to form the ISM hierarchy level partitions. These partitioned levels help in the modeling of framework for ISM methodology approach and thus, resulting in building a directed graph or diagraph that could visually represent the ISM model. The various partitioning of levels is shown in the five iterations conducted in the Tables 5 to 9.

Table 5. Level Partitioning (Iteration 1)

PARAMETER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
E1	1,3,4,5,6,11	1,2,3,4,5,6,7,8,9,10,11,12	1,3,4,5,6,11	**1**
E2	1,2,3,4,5,6,9,10,11	2,3,4,6,7,8,9,10,11,12	2,3,4,6,9,10,11	
E3	1,2,3,4,5,6,10,11,12	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,6,10,11,12	**1**
E4	1,2,3,4,5,6,9,10,11,12	1,2,3,4,5,6,7,8,9,10,11	1,2,3,4,5,6,9,10,11	
E5	1,3,4,5,6,9,10,11	1,2,3,4,5,6,7,8,9,10,11	1,3,4,5,6,9,10,11	**1**
E6	1,2,3,4,5,6,9,10	1,2,3,4,5,6,7,8,10,11	1,2,3,4,5,6,10	
E7	1,2,3,4,5,6,7,8,9,11,12	7,8,11	7,8,11	
E8	1,2,3,4,5,6,7,8,9,10,11,12	7,8,11	7,8,11	
E9	1,2,3,4,5,9,10,12	2,4,5,6,7,8,9,10,11,12	2,4,5,9,10,12	
E10	1,2,3,4,5,6,9,10,11	2,3,4,5,6,8,9,10,11,12	2,3,4,5,6,9,10,11	
E11	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,7,8,10,11	1,2,3,4,5,7,8,10,11	
E12	1,2,3,9,10,12	3,4,7,8,9,11,12	3,9,12	

Table 6. Level Partitioning (Iteration 2)

PARAMETER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
E2	2,4,6,9,10,11	2,4,6,7,8,9,10,11,12	2,4,6,9,10,11	**2**
E4	2,4,6,9,10,11,12	2,4,6,7,8,9,10,11	2,4,6,9,10,11	
E6	2,4,6,9,10	2,4,6,7,8,10,11	2,4,6,10	
E7	2,4,6,7,8,9,11,12	7,8,11	7,8,11	
E8	2,4,6,7,8,9,10,11,12	7,8,11	7,8,11	
E9	2,4,9,10,12	2,4,6,7,8,9,10,11,12	2,4,9,10,12	**2**
E10	2,4,6,9,10,11	2,4,6,8,9,10,11,12	2,4,6,9,10,11	**2**
E11	2,4,6,7,8,9,10,11,12	2,4,7,8,10,11	2,4,7,8,10,11	
E12	2,9,10,12	4,7,8,9,11,12	9,12	

Table 7. Level Partitioning (Iteration 3)

PARAMETER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
E4	4,6,11,12	4,6,7,8,11	4,6,11	
E6	4,6,	4,6,7,8,11	4,6,	**3**
E7	4,6,7,8,11,12	7,8,11	7,8,11	
E8	4,6,7,8,11,12	7,8,11	7,8,11	
E11	4,6,7,8,11,12	4,7,8,11	4,7,8,11	
E12	12	4,7,8,11,12	12	**3**

Table 8. Level Partitioning (Iteration 4)

PARAMETER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
E4	4,11,	4,7,8,11	4,11	**4**
E7	4,7,8,11,	7,8,11	7,8,11	
E8	4,7,8,11,	7,8,11	7,8,11	
E11	4,7,8,11,	4,7,8,11	4,7,8,11	**4**

Table 9. Level Partitioning (Iteration 5)

PARAMETER	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
E7	7,8	7,8	7,8	**5**
E8	7,8	7,8	7,8	**5**

Step 7: Formation of ISM based model framework

Considering the level partitioning developed through multiple iterations of the final reachability matrix, the ISM model framework is generated. The relationship between the various partitions and the enablers that reside in the levels is showcased in the form of a directed graph or diagraph using arrows to project the direction of the influence of enabler form ***i*** to ***j.*** The diagraph shows the relation of the nodes of the enablers with others and their influence in a visually representable manner. The top level of the partitioning is placed at the top of the model framework and the last iteration enablers secure the bottom-most place of the ISM model framework. The nodes of the diagraph are converted to model framework after the transitivity is checked and induced in the framework development. The final model framework generated is displayed in the Figure 4.

Step 8: Study of MICMAC Analysis

MICMAC is an abbreviation for Cross-Impact Matrix Multiplication Applied to Classification when converted from French to English. This analysis aims to correlate the values of driving power and dependence power of the various parameters involved in the ISM methodology approach to establish a contextual inter-relationship of the effect of the enablers on the system. The analysis can help identify and discuss the degree of influential dependencies of various enablers and limelight the enablers that lead the system with their high driving power. This analysis is conducted using the final reachability matrix where the driving power and dependent power values are generated for each enabler. The analysis bifurcates the study into four quadrants, namely Autonomous, Linkage, Independent and Driver factors. Categorization of the quadrants help in easier study of the graph plotted between driver and dependence power of enablers. The four quadrants are explained below:

- **Autonomous Factors:** These factors represent parameters with low driver and dependence power. They are oblivious and incoherent to the system and may have a few links which can be strong.

- **Linkage Factors:** These factors represent a strong driving and dependence power in the system. These enablers act as a feedback loop in the sense that any modification to these parameters will cause a chain reaction and affect the other variables along with getting affected by themselves. The instability of factors in this quadrant often results in them being called as 'relay variables'.
- **Dependent Factors:** These factors represent parameters with low driving power but high dependence power in the system. They constantly rely on the driving enablers and linkage enablers and show high level of robustness when their values are tampered.
- **Driver Factors:** These factors represent parameters with high driving power but low dependence power. These factors are often called as 'key parameters' as they are proactive when it comes to affecting the system dynamics through the enablers associated with the system.

  Incorporating the approach to simplify the ISM study by plotting a graph between driver power and dependence power, the MICMAC analysis plays a crucial role in determining the influential enablers and their relationships that strengthen the system and promote the digital transformation of food SME's. The epilogue of the ISM approach methodology is summarized with the Figure 5 in detail.

4. RESULT AND DISCUSSION

Small and Medium Enterprises are the backbone of the developing nation as it provides the growing population with their demand and hence, the need to optimize the SME's on the strategic as well as production level is necessary for the overall upliftment of the manufacturing sector. Many researchers have discussed about the impact of various enablers on the food SME's and keeping in mind their findings, we have improved the input parameters to incorporate various enablers that also contribute to the development of the upcoming enterprises. The implementation of ISM methodology has proved to provide crucial information regarding the identified enablers and helps develop a hierarchical level partition that simplify the inter-relationship of the enablers involved on a graphically visual representation. The final reachability matrix generated in the Step 5 is shown in the Table 4 which aids the result discussion by providing individual values of driver and dependence power that is later used to develop a scatter diagram for the MICMAC analysis, as shown in the Figure 4 below.

The construction of the scatter plot between driver and dependence power is accentuated with the help of the values obtained from the final reachability matrix which is simplified in the Table 10 mentioned below.

Table 10. Driver and Dependence Power of various enablers identified

Enablers/Parameters		DRIVER POWER	DEPENDENCE POWER
Automation Systems	**E1**	6	12
Cloud Computing	**E2**	9	10
Sensor Aided Cyber Physical Systems (CPS)	**E3**	9	12
Internet of Things (IoT)	**E4**	10	11
Radio Frequency Identification (RFID)	**E5**	8	11
IT Infrastructure	**E6**	8	10
Financial Support	**E7**	11	3
Stakeholder(s) Involvement	**E8**	12	3
Robust Supply Chain management	**E9**	8	10
Information Management	**E10**	9	10
Regulations and Policies	**E11**	12	9
Employee Training and Development	**E12**	6	7

The driver and dependence power attributes of the enablers help develop the scatter plot diagram where the horizontal axis is taken as driver power and vertical axis is taken as dependence power. The bifurcation of the graph plotted is done in four quadrants as mentioned in the Step 8 mentioned in detail above. The result of MICMAC analysis is mentioned in the Figure-3 showcased below.

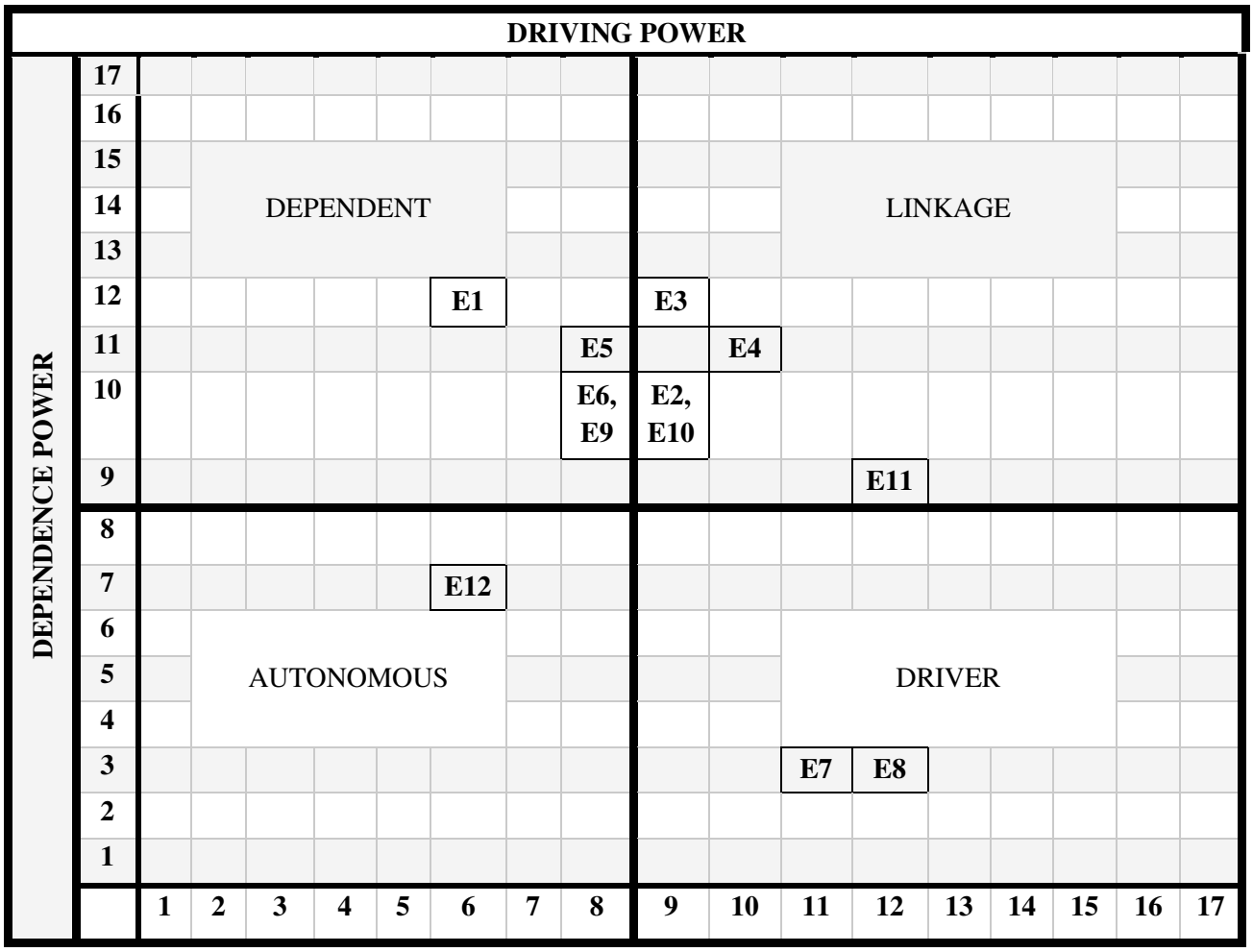

Figure **4.** MICMAC Analysis

It is clear from the graph plotted above that the enablers are scattered in all four quadrants non-uniformly. The detailed interpretation from the MICMAC Analysis is described in the statements below:

- **Driver Quadrant:** This quadrant incorporated the factors that have high driving power and weak dependence power. These factors are generally referred to as key factors as they are responsible for the impactful influence on the system due to the high inter-relationship with other individual enablers. "Financial Support" (E7) and "Stakeholder(s) Involvement" (E8) are the top most drivers out of all the identified enablers with the driving power being 11 and 12 out of 12 respectively. This analysis depicts that there are two individual enablers that have very less dependency (as the dependence power is3 for both the enablers) and therefore, they result in absolute influence on the system and any level of manipulation of these values affect the overall impact of the enablers on the system.
- **Dependent Quadrant:** This quadrant incorporates the factors that have low driving power but a very high dependence power. They are robust when it comes to being affected with enablers of higher driving power and hence, these variables possess high inter-relationship with other parameters involved in this study. There are four enablers that take their place in the dependent quadrant, namely "Automation Systems" (E1), "Radio Frequency Identification (RFID)" (E5), "IT Infrastructure" (E6) and "Robust Supply Chain Management" (E9). These factors have a dependence power of 12, 11, 10 and 10 respectively, explaining that higher value of dependence power clearly shows how the factors get influenced by other factors very strongly and project a very low driving power to influence other factors by them.
- **Linkage Quadrant:** This quadrant consists of the maximum factors out of the 12 selected enablers due to the high driver and dependence power. This shows instability in the system generated through these linkage factors due to the strong affinity of the enablers towards other factors in terms of contextual relationship. There are 5 factors in this quadrant, namely "Cloud Computing" (E2), "Sensor Aided Cyber Physical Systems (CPS)" (E3), "Internet of Things (IoT)" (E4), "Information Management" (E10) and "Regulations and Policies" (E11). These factors are highly influential and also get influenced by other variables in the system and hence, this depicts the strong inter-relationship of the enablers acting in the system. Conversion of the linkage factors into either driver or dependence quadrant will stabilize the system and provide distinct individual factors that either influence or get influenced but at the same time, reduces the level of integration of the enablers of the system which could result in a disruptive management of the enterprise.
- **Autonomous Quadrant:** The final quadrant showcases the factors that have low driver and dependence power in the system. This indicates the inactiveness of the factor in influencing and getting influenced by other active enablers in the system. "Employee Training and Development" (E12) has a driving power of 6 and a dependence power of 7 out of 12, which shows the low proactiveness to optimize the system as compared to other. The balance of driving power and dependence power

denotes how this factor is essential in the system as it works in the background to effectively help the optimization of the system. Increasing the dependency of the factor can shift the prospect of the factor towards dependent quadrant so that the autonomous factors can be minimized.

ISM hierarchy level partitions are useful in the construction of the ISM based model framework as it splits the various identified enablers into levels based on their influential impact on the system. The enablers located at the bottom of the hierarchy depict the strongest impact out of all the enablers placed above them in the level partitioning. The higher levels of partitioning deals with the less influential and impactful enablers that still need to be a part of the system for a smooth flow process of the enterprise. The bifurcation of various enablers based on their iterations is summarized in the Table 11 shown below.

Table 11. Level partitions of the identified enablers

ENABLERS/PARAMETER		LEVEL RANKING
Automation Systems	**E1**	1
Sensor Aided Cyber Physical Systems (CPS)	**E3**	1
Radio Frequency Identification (RFID)	**E5**	1
Cloud Computing	**E2**	2
Robust Supply Chain Management	**E9**	2
Information Management	**E10**	2
IT Infrastructure	**E6**	3
Employee Training and Development	**E12**	3
Internet of Things (IoT)	**E4**	4
Regulations and Policies	**E11**	4
Financial Support	**E7**	5
Stakeholder(s) Involvement	**E8**	5

Based on the table generated above through the 5 iterations that decided the level of partitions, the ISM model framework is developed that could visually represent the outcome of the iterations in a more graphically appealing format. The final ISM based model framework developed is showcased in the Figure 5 below.

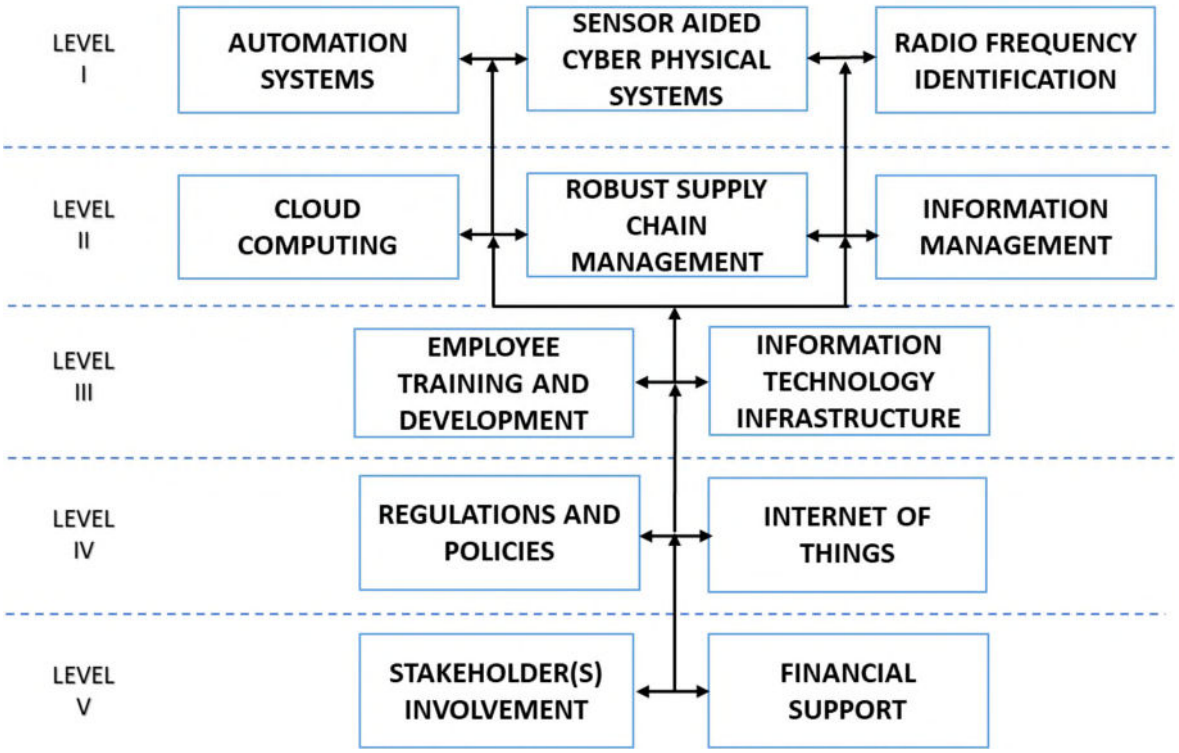

Figure 5. ISM based model framework for the identified enablers

The model framework clearly shows how the financial parameters hold the most crucial place in the digital transformation of food SME's. "Stakeholder(s) Involvement" and "Financial Support" form the base for the developed ISM model by capturing the level 5 and depict that they are the most crucial enablers for the paradigm shift expected in food industries. The financial support influences the combination of technology, organizational and political factors in the model framework in the levels 4 and 3 which include the enablers such as "Regulation and Policies", "Internet of Things", Employee Training and Development" and "Information Technology Infrastructure". The top two levels 2 and 1 comprises more of the technological factors as the influencers and hence, it is observed that the industry needs to focus on the financial aspects to influence and motivate the organization into developing the technological factors and their inculcation in the work methodology of the enterprise. The last two levels of the ISM model framework consist of enablers such as "Cloud Computing", "Robust Supply Chain Management", "Information Management", "Automation System", "Sensor Aided Cyber Physical System" and "Radio Frequency Identification". All the five levels of the model framework are a clear indicator of the degree of influence the enablers have on the system. This is shown as individual effect as well as the effect of the relationships developed between two or more similar factors that can either work in conjunction to each other or indirectly influence or get influenced by other factors available and active in the system.

As the COVID-19 issue persists, small and medium-sized enterprises (SMEs) in the food industry have begun to alter their business strategy. Food SMEs are adopting the digital transformation strategies along with business continuity planning; alternate input source routes; greater emphasis on

inventory management; assessment of people occupational health and safety policies; travel restrictions; and human resource planning make the system more robust. According to the industrial findings, the connection to the internet serves as a foundation for any type of digitalization in the enterprise's workflow, and the top priority enablers theoretically identified are justified in terms of their practical application to aid in the digital transformation of food SMEs in India, as demonstrated by the results of the industrial visit. The impact of research on the local Indian food supply chain as well as the global agriculture supply chain is being investigated.

5. CASE STUDY ILLUSTRATION

After conducting a MICMAC analysis and level partitioning, the researchers discovered that the most important parameters for digital transformation are financial parameters. These are followed by a combination of organizational and technological parameters that are influenced by the level 5 partition parameters. The industrial visit to two small and medium-sized enterprises (SMEs) in North India that are involved in food processing and manufacturing clearly demonstrates the importance of stakeholder involvement and financial support, which are ranked first and second, respectively, in the ISM hierarchy model framework. On the basis of in-depth interviews with management and employees at the company visited, it was determined that the primary motivator for implementing digitalized technologies and management approaches is a stakeholder's willingness and ability to effect change in the traditional way things are done. When stakeholders are involved, they have a greater grasp of the dynamics of the company and are more quickly able to identify bottlenecking issues that need prompt correction. In order to improve the overall well-being of the organization and to incorporate new technologies that might aid in achieving a progressive digital transformation, financial infrastructure and support are very essential.

6. CONCLUSION

As India's population grows and the country becomes more competitive in the global market, small and medium-sized enterprises (SMEs) in the food and beverage industry have the potential to develop at an exponential rate. SMEs provide input to a variety of multinational corporations (MNCs) operating in India, and as a result, they serve to represent the Indian economy by meeting the growing need of the developing country. It can be concluded from the MICMAC analysis and the ISM model framework that Indian SMEs are having financial difficulties when it comes to digital transformation. This demonstrates the urgent need to develop a solution to address the issues related to financial support, the involvement of stakeholders in decision-making, and the development of solution methodologies for the issues that have been identified. Because the majority of these businesses have limited production capacity and employ a small number of people, the necessity to financially support transformation choices is the highest priority in the industry's transition to a new paradigm. When stakeholders are proactive in their involvement in the administration of the organisation and push their

employees to migrate to newer technologies that are accessible, this may be triggered, resulting in increased enterprise growth. Beyond financial factors that form the foundation for digital transformation, a variety of technological and organisational factors also contribute to the process, such as adoption of government policies and local regulations established by top management with the goal of increasing overall enterprise productivity. The implementation of Internet of Things-based services is seen as the first step toward the integration of technology into the digital transformation process. By building an infrastructure for information transport, retrieval, and storage, the Internet of Things in conjunction with information management technologies might provide a brighter and more promising future for businesses as they work towards their goal of digitalization. As a first step toward achieving this goal, it is necessary to provide opportunities for employees affiliated with the organisation to grow, learn new tactics, and develop new skills in order to stay abreast of changing market trends and the likely changes to which the enterprise will be exposed in the near future.

7. **IMPLICATIONS OF THE STUDY:**

Stakeholder participation may bring about economic assistance that can support the company by reducing human error and increasing production while preserving the quality standards set by the firm's rules. Cloud computing and sensors may help integrate cyber physical systems in the workplace, increasing the efficacy of the technologies. This is vital for automating current systems and managing information flow that may be used to verify supply chain management. By combining RFID, cloud computing, and automation technologies, a digitally transformed food industry in India may become more agile and adaptable to changing client demand. The enablers may assist accomplish digital transformation and market it to other businesses. If the digital transformation is effective, this shift in the system allows for a regional or national network of businesses. Various Enterprise Resource Planning (ERP) technologies may be applied to channelize market demand once the SME's are on par with worldwide standards and technical breakthroughs.

REFERENCES

Aggarwal, A., Gupta, S., Jamwal, A., Agrawal, R., Sharma, M., & Dangayach, G. S. (2021). Adoption of smart and sustainable manufacturing practices: An exploratory study of Indian manufacturing companies. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 09544054211040646..

Agrawal S, Jamwal A, Gupta S (2020) Effect of COVID.19 on the India economy and supply chain. *Preprints* 2020050148. https://doi.org/10.20944/preprints202005.0148.v1

Askary, Z., Singh, A., Gupta, S., Shukla, R. K., & Jaiswal, P. (2019). Development of AHP Framework of Sustainable Product Design and Manufacturing of Electric Vehicle. *Advances in Engineering Design* (pp. 415-422). Springer, Singapore.

Attri, R., Dev, N. and Sharma, V., 2013. Interpretive structural modelling (ISM) approach: an overview. *Research Journal of Management Sciences*, *2319*, (1171)

Bader, F. and Rahimifard, S., 2018, September. Challenges for Industrial Robot Applications in Food Manufacturing. In *Proceedings of the 2nd International Symposium on Computer Science and Intelligent Control* (p. 37). ACM.

Besnea, D., Dontu, O., Constantin, V., Spanu, A., Rizescu, C. and Moraru, E., 2018, September. Applications of Additive Technologies in the Food Industry. In *International Conference of Mechatronics and Cyber-Mixmechatronics* (pp. 56-61). Springer, Cham.

BLASI, A., 2018. SCHEDULING FOOD INDUSTRY SYSTEM USING FUZZY LOGIC. *Journal of Theoretical and Applied Information Technology*, *96*(19).

Cai, Y., Lang, Y., Zheng, S. and Zhang, Y., 2015. Research on the influence of e-commerce platform to agricultural logistics: an empirical analysis based on agricultural product marketing. *International Journal of Security and Its Applications*, *9*(10), pp.287-296.

Chen, R.Y., 2017. An intelligent value stream-based approach to collaboration of food traceability cyber physical system by fog computing. *Food Control*, *71*, pp.124-136.

Dangayach, G. S., Gaurav, G., & Gupta, S. (2022). Environmental Impact Assessment of Captive Power Plant Using LCA for Sustainable Development. *International Journal of Social Ecology and Sustainable Development (IJSESD)*, *13*(1), 1-15.

Dangayach, G. S., Gaurav, G., & Gupta, S. (2020). Development of footprint framework of performance measurement system for SMMOs. *Journal of Advances in Management Research*.

Desai, H., Guruvayurappan, D., Merchant, M., Somaiya, S. and Mundra, H., 2017, February. IoT based grocery monitoring system. In *2017 Fourteenth International Conference on Wireless and Optical Communications Networks (WOCN)* (pp. 1-4). IEEE.

Ferrero, R., Gandino, F., Montrucchio, B. and Rebaudengo, M., 2018. A cost-effective proposal for an RFID-based system for agri-food traceability. *International Journal of Ad Hoc and Ubiquitous Computing*, *27*(4), pp.270-280.

Fritz, M. and Schiefer, G., 2002. Market monitoring in dynamic supply networks and chains: An Internet-based support system for the agri-food sector. *Journal on Chain and Network Science*, *2*(2), pp.93-100.

Fu, N., Cheng, T.C.E. and Tian, Z., 2010. RFID investment strategy for fresh food supply chains. *Journal of the Operational Research Society*, pp.1-15.

Galanakis, C.M., 2020. The Food Systems in the Era of the Coronavirus (COVID-19) Pandemic Crisis. *Foods*, *9*(4), p.523.

Gandino, F., Montrucchio, B., Rebaudengo, M. and Sanchez, E.R., 2009. On improving automation by integrating RFID in the traceability management of the agri-food sector. *IEEE Transactions on Industrial Electronics*, *56*(7), pp.2357-2365.

Goue, A.F., Gavriel, A.A. and Drogui, P., 2016. Optimizing The Effectiveness Of HACCP In Agri-Food SMEs. *European Scientific Journal, ESJ*, *12*(24), p.18.

Gupta, S. (2016). Some Issues In Sustainable Manufacturing: A Select Study Of Indian Manufacturing Companies.. (Doctoral dissertation, MNIT Jaipur).

Gupta, S., Dangayach, G. S., Singh, A. K., Meena, M. L., & Rao, P. N. (2018). Adoption of sustainable supply operation quality practices and their impact on stakeholder's performance and sustainable performance for sustainable competitiveness in Indian manufacturing companies. *International Journal of Intelligent Enterprise*, 5(1-2), 108-124.

Gupta, S., Dangayach, G. S., Singh, A. K., Meena, M. L., & Rao, P. N. (2018). Implementation of sustainable manufacturing practices in Indian manufacturing companies. *Benchmarking: An International Journal.*

Harun, Z., Reda, E. and Hashim, H., 2018, March. Real time fish pond monitoring and automation using Arduino. In *IOP Conference Series: Materials Science and Engineering* (Vol. 340, No. 1, p. 012014). IOP Publishing.

India Brand Equity Foundation (2019). https://www.ibef.org/industry/retail-india.aspx (Accessed on February 26, 2019).

Iqbal, J., Khan, Z.H. and Khalid, A., 2017. Prospects of robotics in food industry. *Food Science and Technology*, *37*(2), pp.159-165.

Jałmużna, I.B., Królikowski, J. and Sadok, M., 2018, October. Visualization System Design for the Process of Packaging Egg Powders. In *International Conference on Human Systems Engineering and Design: Future Trends and Applications* (pp. 1113-1119). Springer, Cham.

Jamwal, A., Aggarwal, A., Gupta, S., & Sharma, P. (2019). A study on the barriers to lean manufacturing implementation for small-scale industries in Himachal region (India). *International Journal of Intelligent Enterprise*, 6(2-4), 393-407.

Jamwal, A., Agrawal, R., Gupta, S., Dangayach, G. S., Sharma, M., &Sohag, M. A. Z. (2020). Modelling of sustainable manufacturing barriers in pharmaceutical industries of Himachal Pradesh: an ISM.fuzzy approach. In Proceedings of International Conference in Mechanical and Energy Technology (pp. 157.167). Springer, Singapore.

Jamwal, A., Agrawal, R., Sharma, M., & Kumar, V. (2021). Review on multi.criteria decision analysis in sustainable manufacturing decision making. International Journal of Sustainable Engineering, 1.24.

Kamble, S.S., Gunasekaran, A. and Sharma, R., 2018. Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry. *Computers in Industry*, *101*, pp.107-119.

Khan, Z.H., Khalid, A. and Iqbal, J., 2018. Towards realizing robotic potential in future intelligent food manufacturing systems. *Innovative Food Science & Emerging Technologies*.

Kopishynska, O.P., Utkin, Y.V., Voloshko, S.V., Sliusar, I.I. and Kartashova, O.G., 2018, May. Algorithm of creating of an efficient cooperation between universities, business companies and agriculture enterprises during studying and implementation of information systems. In *2018 IEEE 9th*

International Conference on Dependable Systems, Services and Technologies (DESSERT) (pp. 682-686). IEEE.

Kosior, K., 2018. Digital Transformation in the Agri-Food Sector-Opportunities and Challenges. *RocznikiNaukoweStowarzyszeniaEkonomistówRolnictwaiAgrobiznesu*, *20*(2), pp.98-104.

Koszela, K., Raba, B., Zaborowicz, M., Przybył, K., Wojcieszak, D., Czekała, W., Ludwiczak, A., Przybylak, A., Boniecki, P. and Przybył, J., 2015, July. Computer image analysis in caryopses quality evaluation as exemplified by malting barley. In *Seventh International Conference on Digital Image Processing (ICDIP 2015)* (Vol. 9631, p. 96310V).

Krishnan, S., Gupta, S., Kaliyan, M., Kumar, V., & Garza-Reyes, J. A. (2021). Assessing the key enablers for Industry 4.0 adoption using MICMAC analysis: a case study. *International Journal of Productivity and Performance Management*.

Lavelli, V., 2013. High-warranty traceability system in the poultry meat supply chain: A medium-sized enterprise case study. *Food control*, *33*(1), pp.148-156.

Lefebvre, V.M., De Steur, H. and Gellynck, X., 2015. External sources for innovation in food SMEs. *British Food Journal*, *117*(1), pp.412-430.

Manivannan, P., Kesavan, D., Anuradha, M.R. and Vetrivel, V., 2020. Impact of Covid 19 on Online Food Delivery Industry With Reference To Operational and Revenue Parameters. *Purakala with ISSN 0971-2143 is an UGC CARE Journal*, *31*(31), pp.142-152.

Maria, N., Zaid, A., Catrin, S., Ahmed, K., Ahmed, A.J., Christos, I., Maliha, A. and Riaz, A., 2020. The socio-economic implications of the coronavirus pandemic (COVID-19): A review. *International Journal of Surgery*, *78*, pp.185-193.

Ndou, V., Schina, L., Passiante, G., Del Vecchio, P. and De Maggio, M., 2010, April. Toward an open network business approach. In *4th IEEE International Conference on Digital Ecosystems and Technologies* (pp. 282-287). IEEE.

Ostrouh, A.V. and Kuftinova, N.G., 2012. Automation of planning and management of the transportation of production for food-processing industry enterprises. *Automatic control and computer sciences*, *46*(1), pp.41-48.

Patidar, L., Soni, V.K. and Soni, P.K., 2017. Manufacturing wastes analysis in lean environment: an integrated ISM-fuzzy MICMAC approach. *International Journal of System Assurance Engineering and Management*, *8*(2), pp.1783-1809.

Prathipati, B. S., Jamwal, A., Agrawal, R., & Gupta, S. (2021). Analysis of the Challenges of Industry 4.0-Enabled Sustainable Manufacturing Through DEMATEL Approach. In *Advances in Industrial and Production Engineering* (pp. 579-587). Springer, Singapore.

Ping-Zeng, L., Yong, L. and Shu-Sheng, B., 2009, September. Design of intelligent monitoring and controlling system for foodstuff deepfreeze. In *2009 International Conference on Scalable Computing and Communications; Eighth International Conference on Embedded Computing* (pp. 381-386). IEEE.

Sharma, A., Gahalot, P., Talib, S., Gupta, S., Gautam, N., Singh, A., & Goswami, U. (2022). Design and Development of Industry 4.0-Enabled Monitoring System. In *Advances in Mechanical and Materials Technology* (pp. 809-815). Springer, Singapore.

Singh, A., Askary, Z., Gupta, S., Sharma, A. K., & Shrivastava, P. (2019). AHP Based Model for Evaluation of Sustainable Manufacturing Enablers in Indian Manufacturing Companies. *Advances in Industrial and Production Engineering* (pp. 397-403). Springer, Singapore.

Sushil, 2018. How to check correctness of total interpretive structural models?. *Annals of Operations Research*, *270*(1-2), pp.473-487.

The Economic Times, 2019. https://economictimes.indiatimes.com/industry/cons-products/food/indias-food-processing-sector-may-attract-33-billion-by-2024-study/articleshow/61737009.cms?from=mdr (Accessed on May13, 2019).

Trebar, M., Grah, A., Melcon, A.A. and Parreno, A., 2011, September. Towards RFID traceability systems of farmed fish supply chain. In *SoftCOM 2011, 19th International Conference on Software, Telecommunications and Computer Networks* (pp. 1-6). IEEE.

Ushada, M., Okayama, T., Khuriyati, N. and Suyantohadi, A., 2017. Affective Temperature Control in Food SMEs using Artificial Neural Network. *Applied Artificial Intelligence*, *31*(7-8), pp.555-567.

Valiaveetil, J. J., Singh, S., Jain, A., & Gupta, S. (2019). Design and Development of an Online Process Measurement System for Zero Defect Production. *Advances in Industrial and Production Engineering* (pp. 791-800). Springer, Singapore.

Van der Loo, S., Chen, L., Edwards, P., Holden, J.A., Karamperidis, S., Kollingbaum, M.J., Marqui, A.C., Nelson, J.D., Norman, T.J., Piecyk, M. and Pignotti, E., 2015. Development of a digital tool to overcome the challenges of rural food SMEs. *Scottish Geographical Journal*, *131*(3-4), pp.212-219.

Vignali, G., Bertolini, M., Bottani, E., Di Donato, L., Ferraro, A. and Longo, F., 2017. Design and Testing of an Augmented Reality Solution to Enhance Operator Safety in the Food Industry. *International Journal of Food Engineering*, *14*(2).

Walker, B. and Barnes, S.J., 2005. Wireless sales force automation: concept and cases. *International Journal of Mobile Communications*, *3*(4), pp.411-427.

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