An I.S.M.-Based Study on the Interactions Among Technology Adoption Drivers in Dairy Farming

Hans Kaushik*
Rohit Rajwanshi**
Artee Bhadauria***

ABSTRACT

India is the largest producer and consumer of milk worldwide, with a contribution of more than 26,000 million USD to the Nation's G.D.P. but lacks in terms of yield, overall dairy farm output and effective herd management. In agribusiness, technology has led to significant transformation in many countries to achieve operational efficiency, support decision-making, enhance productivity and achieve sustainability. This research explores linkages among technology adoption drivers that facilitate the adoption process. The researchers have conducted personal interviews with dairy farm owners/managers across three Indian states. Finally, an N.G.T.-based discussion led by an expert team comprised of dairy industry managers and technical specialists, as well as academics, assisted in generating the final list of fourteen drivers and establishing the contextual relationships among them. I.S.M. was used to examine the interactions among drivers as part of the soft systems approach, starting with building a structural self-interaction matrix (SSIM), initial and final reach ability matrix, and level partition at the end. Hygiene considerations, breeding enhancement, streamlined operations, and other factors were shown to be essential drivers of technology adoption in dairy farming in the digraph. Overall, dairy farm management was the most dependent factor, followed by sustainability, cost control, profitability, etc. Further, all MICMAC classified all drivers per driving and dependence power

Keywords: Dairy farming, technology adoption, nominal group technique (N.G.T.), interpretive structural modeling (I.S.M.), MICMAC analysis.

1. INTRODUCTION

Milk is an indispensable requirement of human life as it cannot be perfectly substituted. In many ways, the dairy sector stands apart from the rest of the agricultural industry. Milk is produced on a daily routine basis, providing a steady income to a large number of small farmers. Milk production is a labor-intensive industry that employs a large number of people. Due to the economically susceptible position of small dairy farmers, the dairy industry has the highest level of protection. Often known as white gold, milk can manufacture a wide range of high-quality items (Deshmukh, 2015). Milk is a base raw material for other dairy products like ice cream, yogurt, cheese, cottage cheese, butter, buttermilk, etc. These are obtained by processing the milk at different stages and forms (Muehlhoff et al., 2013). Due to the ubiquity of milk and related products across the globe, the dairy sector has been an

* Research Scholar, Department of Management, Dayalbagh Educational Institute, Agra (U.P.), India; hanskaushikdayalbagh@gmail.com
** Assistant Professor, Department of Management, Dayalbagh Educational Institute, Agra (U.P.), India; rohit0108@yahoo.com
*** Research Scholar, Department of Management, Dayalbagh Educational Institute, Agra (U.P.), India; bhadauriaaarti@gmail.com

important research area for researchers from veterinary (science), engineering and management backgrounds. More interest inclination has been observed since the intervention of technology in dairy processing. At the beginning of the 21st century, technological adoption took the focus of the studies as a significant prospect for dairy operations (Shah, 2001). Since then, with the help of surveys, pilot studies, and case studies, many researchers have tried to systematically analyze and prove technology adoption as a benchmark tactic for enhancing productivity, quality management and overall efficiency of the dairy farm and supply chain. Later, technology involved in the dairy industry has parallel progress with technological advancements. Several new concepts in technology, including some general and some customized ones for dairy technology, were introduced, discussed and experimented with to prove positive results.

Some popular technologies used in dairy farming are - using various IT/ICT tools for managing databases like records, usage of radio frequency identification (RFID) tags to spot real-time monitoring data of animals, artificial insemination for creating good breeds of animals, mechanized silage preparation and distribution, automatic milking through milk parlors, bucket milking system, robotic milking system, portable milking system and using miscellaneous machinery like hydraulics for cleaning, silage preparer and distributor etc. Some dairy farms extend their operations to produce packaged milk and related products. Such farms use other dairy plant-based technologies like chilling plants, packaging and labeling machinery, etc.

As a part of agriculture, the dairy business in India has always been a significant contributor to the Nation's G.D.P., i.e., approximately 26,000 million USD (Deshmukh, 2014). The dairy market review of March 2020 (assessing 2018-19 production) reported significant growth of 1.4% producing 852 million tonnes of milk across the globe, with India achieving rank 1. In the Asian context, over 90 percent of total output comes from India and Pakistan, balancing the decline witnessed in other Asian countries. India has shown favorable growth of 4.5% from 2017-18 levels. Initially, Indian milk production was 20 million tonnes in 1970. In 2018-19, the country produced 187.70 million tonnes, with per capita availability as 394 grams/day, up from 176.40 million tonnes in 2017-18 and 165.40 million tonnes in 2016-17 (NDDB Reports: 2016-17, 17-18, and 18-19). This made India retain its position as the largest milk-producing country, followed by European Union. It is also evident that the growth in the production levels is at a slower pace when it comes to matching the rise in the country's demand Nozaki (2017). The milk co-operatives society system of milk supply in India is famous across the globe.

Various studies have pointed out the need for technology adoption in dairy farming methods from procurement to end consumers covering every supply chain level. National Dairy Development Board (NDDB) promotes farmer training related to technology adoption. Genetic technology is discussed, and NDDB promotes an Internet-based dairy information system (i-DIS) for milk cooperatives to provide mutual benefits. In current prevailing situations, innovative and sustainable solutions across operations have become essential for agriculture to be cost-effective, save future requirements and consider environmental impact. As per the global scenario, the dairy business has essentially included technology engagement known as precision dairy farming (Schroeder, 2015) or smart dairy farming (Vote-U-Lan, 2017), primarily in the United States of America. Precision dairy farming entails a fully automated process from milking the cow until the procurement, testing, manufacturing, and packing tasks are completed. Smart farming is similar but defined in the context of the IoT-enabled dairy farm. It is stated that to attain operational efficiency and value delivery, the future of India's dairy farming business lies in the hands of technology and the dairy business is successfully driven by technology.

India's dairy sector has played an essential part in the growth of the country's agribusiness. Dairy farming has been industrialized, resulting in optimal assimilation of the milking unit (the cow), the operator (the farmer), technology and equipment (engineering) and the production environment (the dairy farm). Producing extra milk with fewer dairy cows increases farm unit economic performance while dramatically reducing the country's ecological imbalance (Deshmukh, 2015). Prevailing agricultural traditions do not entirely restrict farmers in India; they also incorporate many innovative ideas and techniques into their farming methods. Through extension services, the integration of cooperative principles has enabled even small Indian dairy farmers to have technological access to sophisticated and up-to-date knowledge.

The concern about ensuring an economically and environmentally sustainable food supply has grown in response to the rise in global demand and production due to the increase in population size. Thus, agriculture has evolved into many agribusinesses supported by high productivity levels in international markets and supply chains (Zanin *et al.*, 2020). Further, as a consequence of the continuing pressure on farm incomes, the emergence of animal illnesses with a substantial influence on animal welfare concerns and agricultural-related environmental problems has altogether grown attention to the conception of "sustainable" farming methods (Van calker, 2005). Smallholders in the dairy business are the primary source of income for the local economy and achieving sustainability. While dealing with socioeconomic issues is a significant concern for the industry. For long-term sustainability, research can help overcome socioeconomic difficulties, adopt technology and innovation, create products, and adopt environmentally friendly practices (Kongo, 2016).

According to Nozaki (2017), India should get its unorganized milk sector into the main channel of the organized one to fulfill the steady surge in milk demand. According to the National dairy development board(NDDB), the current National Dairy Plan aims for 64% of its milk production through the organized sector by 2023. The major problem in the dairy sector is milk procurement due to low animal productivity or bovine yield (Milking animals). With the Ministry of Animal Husbandry and Fisheries of India's efforts, the NDDB aims to improve animal health and breeding concerns using RFID tags and artificial insemination technologies.

The use of modern technologies such as I.C.T. adoption, artificial insemination, RFID tagging, ERP, online payments, procurement, marketing, record keeping, the installation of automated milk collection units, and G.I.S. enabled tracking in the logistics part of the supply chain could assist the Indian dairy industry in redefining and reshaping the value chain. Timely innovation is required for continual quality improvement (Nalla, 2014).

Various studies conducted across the world have stressed the importance of technology adoption in the dairy business. There are papers and articles about technology adoption in dairy farms and the dairy industry. Some studies dealt with technology adoption or the technology role in the dairy business, while others focused solely on the factors influencing technology adoption and management. Numerous case studies, success stories, expert reviews, and exploratory and conclusive research have been published that examine enabling factors influencing technology adoption in dairy farming. In general, the drivers can be inhibitors or enablers. It is evident that the factors (inhibitors or enablers) impact the other(s) and get impacted by the other(s).Some studies focus on general factors influencing technology adoption and their impact on the technology adoption and management process. However, this paper focuses on identifying and analyzing the interactions within technology adoption drivers that enable the adoption. Thus, it is essential to identify the list of technology adoption-enabling drivers most significant in driving the drivers and those dependent on the other drivers. The goal is to pick a small, focused set of elements, highlight its broadness, and analyze and resolve the complexity caused by many interactions among the set's elements.

2. REVIEW OF LITERATURE

Subburaj et al. (2015) proposed five crucial critical areas for improving operational efficiency with particular reference to the dairy supply chain prevailing in the Tamil Nadu state of India, emphasizing the importance of integrated-animal health planning using information technology. Another paper in the Indian context reveals that, as the sustainability aspect of dairy farming emerges in India, with expected high demand for dairy products, significant opportunities should be created through technological innovations to increase the income of rural-based dairy systems, thereby reducing poverty and reducing soil health deterioration. Thus, technological advances and the ability to transfer technology from labs to fields are required in the dairy farming system to reduce production costs and increase economic returns to farmers. (Randhawa, 2016)

McDonald et al. (2015) measured the perception of technology ease-of-use in three types: financial management technology, grassland measurement technology and artificial insemination. Artificial insemination and farm-financial management technology got higher rankings for ease of use than grassland measurement.

Regarding small and medium firms in the Greek dairy supply chain, Ghadge et al. (2017) identified the drivers for enhancing environmental sustainability performance. It was pointed out that to acquire market share and differentiate from competitors, dairy businesses are increasingly investing in environmentally sustainable technologies in their operations.

Vote-u-lan et al. (2017) presented a case study of farmers in Ontario (Canada) that have implemented intelligent dairy farming technology, which employs IoT technology in activities such as digital cow tracking, sensor-enabled fodder crop management, digitally signaled births, genetic testing, and so on. The study concludes that technology adoption aids in data collection, production quality, and environmental protection.

Bracke et al. (2009) concluded in their animal welfare report in the European context that there should be appropriate animal welfare policies, intensive farm husbandry systems, and scientific and technological state of the art as operational efficiency and cost reduction have both become critical drivers for developing housing and management systems for farm animals.

Precision dairy farming refers to technology engagement in the dairy business that helps to measure and analyze animal behavior, physiological records and milk production-related indicators. It entails automating procedures such as feeding and milking, updating data, keeping records, and monitoring the health of milking units. It provides improved methods of monitoring and increasing animal well-being to reduce labor dependency and costs and increase the life expectancy of milking units. As a result, precise technologies will propel the dairy business forward.(Schroeder, 2015)

New disruptive I.C.T. technologies such as RFID tags, the internet of things (IoT), mobile applications, etc., in conjunction with ERP in collecting real-time data in cattle farms, aid in cost reduction, milk production, animal breeding, animal health, and overall efficiency. It can also execute cow farms' technological inclusion and modernize the entire Indian dairy industry by initiating a new growth age (Jadawala & Patel, 2018).

The World dairy situation report 2019 by International Dairy Federation (I.D.F.) indicated science-based expertise as an improvement area that plays an important role. Dairy product quality, healthy animals, farm productivity and sustainability are the dairy industry's key drivers. There is a need for continuous improvement in order to provide nutritious, safe and sustainable dairy. More governments are also required to contribute and positively promote dairy at various International platforms like W.H.O., F.A.O., U.N. and Codex meetings.

3. PROBLEM DESCRIPTION

A thorough review of the literature discovered that research in the dairy sector needs to be expanded. In the case of India's dairy business, less number of researches talks about only dairy farm-level technologies, which are the root of the supply chain and require more attention to cop with the productivity and overall dairy farm performance-related issues. It primarily considers complete supply chain practices in dairy plants and factors affecting technology adoption across the chain. Several classical technology adoption models exist that portray the technology adoption dynamics under several categories. However, according to the systems perspective, several interactions exist among the elements in each category. Soft systems methodology (S.S.M.) is used under a complex environment and pluralistic approach (Checkland, 1989; Jackson, 2000). The pluralistic approach can be understood as a cost-benefit trade-off. If a solid needs to gain benefits, it has to incur some cost and controlling the cost is also a concern for businesses. Likewise, to gain the benefits of effectively and efficiently managing the dairy farm, farmers need to incur the cost of technology adoption.

There are several existing technology adoption models that began from the change model and then the innovation adoption model and further led the path towards multiple versions of the Technology acceptance model (T.A.M.) by Davis (1989) and associates in order to make a better understanding about the dynamics of technology adoption. After analyzing several papers in journals, government reports and articles, it was found that dairy farming in India has a lot of socio cultural impacts involved other than technology-related factors and thus, complexity arises. Cow milking is mainly associated with religious sentiments, and thus the supporters of traditional dairy farming methods are somewhat reluctant to adopt technologies aggressively. Several papers highlight various enabling drivers that stimulate technology adoption in dairy farming. All the drivers have multiple linkages, meaning that every driver affects the other and gets affected by others. Ultimately a web-like structure is formed with almost no derived conclusion. This opens the research domain to look for a tiered model that may simplify this complexity by dividing the drivers into several hierarchical layers based on driving and dependence order. This provides a base to highlight the importance of technology adoption in dairy and a clear picture to the decision-makers for effective technology adoption. The primary purpose of this research is to identify and list the drivers of technology adoption in the dairy farming business and to study the interactions among the identified drivers.

As a result, by proposing an I.S.M. model, this research study addresses the driving elements responsible for enabling technology adoption in the dairy business and their hierarchical relationships.

4. OBJECTIVES OF STUDY

Objective 1: To identify the factors enabling (drivers) technology adoption in dairy farming

Objective 2: To establish the relevant relation between identified drivers of technology adoption through an ISM-based model

Objective 3: To classify the identified drivers of technology adoption based on MICMAC analysis

5. METHODOLOGY

In recent research, an interpretative structural modeling (I.S.M.) approach has been applied as a solution methodology. It aids in the understanding of the contextual linkages among drivers. The complete step-by-step approach used in this research is explained in **Error! Reference source not found.**.

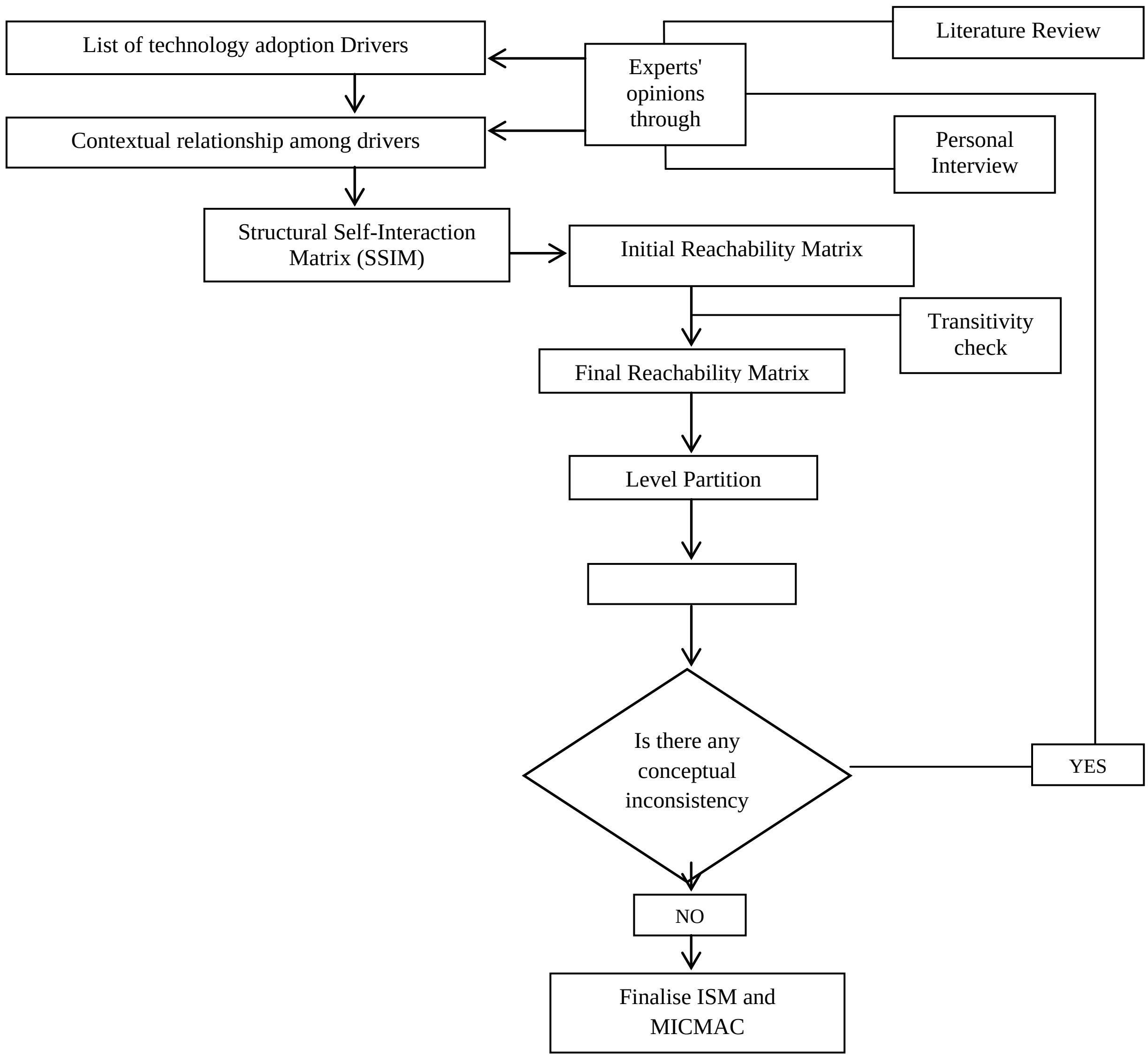

Fig. 1 : I.S.M. Methodology for Analyzing the Hierarchy Among the Drivers

5.1 Nominal Group Technique

The nominal group technique (N.G.T.) is highly effective and efficient as a piece of information or idea-generating instrument and consensus development mechanism under soft systems methodology (Harvey & Holmes, 2012). It is a planned method for dissipating the effect of group members who tend to dominate the discussion and solicit responses from relatively silent individuals. As a result, each member has a say and can vote on each item. As a result, N.G.T. entails organized brainstorming and decision-making, ideally among 5 to 9 members (Srivastava, 2014). This research work has used the N.G.T. approach among experts to finalize the list of elements and to figure out the relevance relationship among the identified elements, which ultimately helped to develop the I.S.M. and MICMAC. The expert team of seven was composed of three academicians, two dairy farm owners, and two members from the dairy development board.

5.2 Interpretive Structural Modelling (I.S.M.)

Prof. J. Warfield developed the I.S.M. technique to research socioeconomic systems under complexity. I.S.M. is used to recognize contextual relationships among items connected with a problem to be investigated in a methodical approach (Warfield, 1974). I.S.M. converts a fuzzy system model into a hierarchical digraph. I.S.M. is a methodical thinking strategy that allows for various intricate relationships between elements (Jharkharia & Shankar, 2004). I.S.M. includes experts' opinions by supporting multiple ways for generating contextual links among elements through nominal group technique, brainstorming and affinity diagramming (Ravi & Shankar, 2005).

5.3 MICMAC

Cross-Impact Matrix Multiplication Applied to Classification is what it is called. Duperrin and Godet created the Matrice d'Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) (1973). MICMAC analysis entails creating a graph that classifies the elements under investigation as per the dependence and driving power. This work uses MICMAC analysis to classify the identified drivers of technology adoption.

6. FINDINGS AND ANALYSIS

6.1 Identification of Drivers

Some drivers of technology adoption in the dairy farm have been listed as elements through a literature review to form the base for the first objective of this research. The word 'element' is more generic in the context of I.S.M. that is used to refer to a variable or a factor, and here in this research context, it is reflected for drivers. In order to confirm the presence of identified elements in a natural environment, the researcher has conducted personal in-depth interviews with 60 dairy farm owners/managers from three states of North India- Punjab, Haryana and Uttar Pradesh. The list of 12 drivers was provided to a panel of 7 dairy specialists comprised of academicians, dairy farm owners, researchers, and scientists from dairy research institutions after the literature analysis and interview results were taken into account. The study's first goal has been accomplished with the identification of elements. As a procedural requirement for I.S.M., the immediate need for experts' opinions is taken to strike off, add, modify, rephrase or split the presented elements. After N.G.T.-based discussion among the expert members, all 12 drivers from the interviews were taken, and experts added two additional drivers- 'standardized and streamlined operations' and 'effective resource utilization. Thus, the final list of 14 drivers was established, given in Table 1, along with the frequency of claims by dairy farm owners/managers. The description of the identified elements based on the experts' opinions is indicated below:

Table 1 : Final List of Identified Drivers

S. No.	Elements (Drivers)	Personal Interviews with Dairy farms		Introduced by experts
		Indicated by dairy farms	No. of dairy farms claiming	
1	Time-saving	Yes	46	
2	Reducing human efforts	Yes	40	
3	Quality improvement	Yes	40	
4	Cost Control	Yes	31	
5	Safety/Hygiene	Yes	32	
6	Breeding improvement	Yes	44	
7	Real-time monitoring-	Yes	16	
8	Profitable	Yes	19	
9	Overall, dairy farm management	Yes	41	
10	Ease of work	Yes	35	
11	Sustainability	Yes	21	
12	Standardization and streamlining operations	-	-	Yes
13	Improved yield	Yes	33	
14	Effective Resource utilisation	-	-	Yes

i) **Time-Saving–** Adopting technology saves time as parallel operations like milking, recording, monitoring and other activities can be handled simultaneously. Also, installing an automatic milking system can manage the milking of large herd sizes at a given time.

ii) **Reducing Human Efforts–** Large dairy farms may require a large workforce to get involved in the milking process and other tasks. Technology intervention can reduce this dependence, and human efforts can be utilized in developing the managerial brain behind dairy farm operations.

iii) **Quality Improvement–** This element is essentially about total quality management (TQM) principles such as quality enhancement in managing operations, avoiding delays and wastages, better breed and milk quality, animal health detection mechanism etc.

iv) **Cost Control–** It talks about the cost optimization principle. Also, it is essential to note here that the cost control of technology adopted-dairy farm operations is on a long-term basis. In the short term, the fixed and maintenance costs can probably incur high costs in the initial phase.

v) **Safety/Hygiene–** Safety consideration is associated with the health and safety of animals, and hygiene is related to the human contact-less milking process. With the help of automatic milking, milk can be protected from bacterial impact from manual milking.

vi) **Breeding Improvement–** This element focuses on the milking animal breed improvement through artificial insemination (A.I.) adoption. A.I. is nowadays a popular and widely acceptable process of developing good quality bull semen in the labs for breeding purposes.

vii) **Real-Time Monitoring–** Real-time monitoring of cattle is possible with the help of RFID tagging that automatically updates each milking unit's heat, health, milking and physical activity-related data.

Some dairy farms use pedometers to detect the movements of cattle. If movements deviate from standard levels, a check-up requirement for animals arises.

viii) **Profitable–** The technology adoption can generate profitability in the long run. The explanation of long-term profitability is similar to that of cost control.

ix) **Overall Dairy Farm Management–** The adoption of technology thus helps to manage the overall activities and operations of a dairy farm. This element considers the broad impact of adopting various technologies across the dairy farm.

x) **Ease of Work–** Technology adoption facilitates ease of handling the routine-based activities of a dairy farm by dividing some task load of humans.

xi) **Sustainability–** Sustainability is primarily connected with human, economic, social and environmental areas. It is aimed at planning the preservation of these resources for future generations. Technology adoption in dairy farm activities promotes the upcoming generations to engage them in opting for professional education or training to enhance their skills and abilities to look for innovative methods for developing this concerned domain. Also, some additional operations, such as maintaining a bio-gas technology plant and using related dairy farm-based by-products such as cow urine and dung for medicinal and manure preparation, are a positive concern for the environment. Under economic consideration, it promotes the efficient and effective use of assets to maintain profitability over time.

xii) **Standardization and Streamlining Operations–** Adopting technology brings standardized and properly streamlined operations. In the context of dairy farm operations, there is a negligible requirement for customization; therefore, technology adoption assists the networking and standardized functioning of all routine activities.

xiii) **Improved Yield–** Yield per cattle is a significant performance indicator of a dairy farm. It refers to the daily capacity of milk quantity delivered by a single milking unit. Technology adoption can improve the productivity of animals through technology-enabled breeding, timely heat and health issue detection through monitoring.

xiv) **Effective Resource Utilization–** Technology adoption enables effective resource utilization, be it monitory, human, material resources etc., in a dairy farm. The dairy farm output is not standalone or isolated from milk production, but various related by-products can also be utilized. The wastages are also reduced due to properly planned and coordinated operations.

6.2 Relevance Relation Between Identified Drivers

I. Structural Self-Interaction Matrix (SSIM)

After listing drivers, SSIM or VAXO framework was created at the next step in the process of developing I.S.M. in order to determine the relevant relationship between all fourteen drivers (Table 2).

Rules for SSIM :

Step 1: Number the elements Furthermore, put them in a sequence (row-wise and column-wise) such that a matrix-type structure is created so to get the nxn number of cells (where "n" is the total number of identified elements).

Step 2: Choose and consider each cell at a time, and ask the experts to define the type of relationship between the corresponding column and row of the selected cell.

If a chosen row element "i" is affecting the corresponding column element "j," then write **"V"** in the cell. If "i" is affected by "j," then indicate **"A**." Mark **"X"** if there is interdependence, which indicates both affect each other and **"O"** if there is no association.

Table 2 : Structural Self-Interaction Matrix (SSIM)

		Time-saving	Reducing human efforts	Quality improvement	Cost Control	Safety/Hygiene	Breeding improvement	Real-time monitoring	Profitable	Overall dairy farming management	Ease of work	Sustainability	Standardization and streamlining operations	Improved yield	Effective Resource utilisation
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Time-saving	**1**		X	A	V	O	O	A	V	O	A	X	A	O	X
Reducing human efforts	**2**			O	V	A	O	A	V	O	A	X	A	O	X
Quality improvement	**3**				V	X	A	A	V	V	O	X	A	V	X
Cost Control	**4**					A	A	A	X	V	A	X	A	O	A
Safety/Hygiene	**5**						X	A	V	V	V	V	A	V	O
Breeding improvement	**6**							O	V	V	V	O	O	V	O
Real-time monitoring-Managing herd performance	**7**								V	V	V	V	V	V	V
Profitable	**8**									X	A	X	A	A	A
Overall dairy farming management	**9**										A	X	A	A	A
Ease of work	**10**											O	A	O	A
Sustainability	**11**												A	A	X
Standardization and streamlining operations	**12**													O	A
Improved yield	**13**														O
Effective Resource utilisation	**14**														

II. Formation of Initial Reachability Matrix

The initial reachability matrix is formed from the SSIM. It is a binary matrix with the values 0 and 1, and the directions are as follows:

- In place of 'V' at any cell location, "i, j" write 1 and 0 at cell "j, i."
- In place of 'A' at any cell location, "i, j" write 0 and 1 at cell "j, i."
- In place of 'X' at any cell location, "i, j" write 1 and 1 at cell "j, i."
- In place of 'O' at any cell location, "i, j" write 0 and write 0 at cell "j, i."

The initial reachability matrix is indicated in Table 3.

Table 3 : Initial Reachability Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	1	0	1	0	0	0	1	0	0	1	0	0	1
2	1	1	0	1	0	0	0	1	0	0	1	0	0	1
3	1	0	1	1	1	0	1	1	1	0	1	0	1	1
4	0	0	0	1	0	0	0	1	1	0	1	0	0	0
5	0	1	1	1	1	1	0	1	1	1	1	0	1	0
6	0	0	1	1	1	1	0	1	1	1	0	0	1	0
7	1	1	1	1	1	0	1	1	1	1	1	1	1	1
8	1	0	0	1	0	0	0	1	1	0	1	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0
10	1	1	0	1	0	0	0	1	1	1	0	0	1	0
11	1	1	0	1	0	0	0	1	1	0	1	0	0	1
12	1	1	1	1	1	0	0	1	1	1	1	1	0	0
13	0	0	0	0	0	0	0	1	1	0	1	0	1	0
14	1	1	1	1	0	0	0	1	1	1	1	1	0	1

III. Deriving Final Reachability Matrix

The initial reachability matrix is converted to the final reachability matrix (Table 4). The final reachability matrix is created using the transitivity check rule for a missing relationship which means if the relationship has been defined between A and B along with the relationship between B and C, but by mistake relationship between A and C is left to be defined.

Following the transitivity check, each element's row and column totals are calculated. The row total indicates the driving power of each element, and the column total indicates the dependence power. The number of elements with which a given element has a dependent or driving influence is referred to as power. These powers are put to use in the development of the MICMAC.

Table 4 : Final Reachability Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	D.R.
1	1	1	1	1	0	0	0	1	1	1	1	1	0	1	**10**
2	1	1	1	1	0	0	0	1	1	1	1	1	0	1	**10**
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**14**
4	1	1	0	1	0	0	0	1	1	0	1	0	0	1	**7**
5	1	1	1	1	1	1	1	1	1	1	1	0	1	1	**13**
6	1	1	1	1	1	1	1	1	1	1	1	0	1	1	**13**
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**14**
8	1	1	0	1	0	0	0	1	1	0	1	0	0	1	**7**
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
10	1	1	0	1	0	0	0	1	1	1	1	0	1	1	**9**
11	1	1	1	1	0	0	0	1	1	1	1	1	0	1	**10**
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**14**
13	1	1	0	1	0	0	0	1	1	0	1	0	1	1	**8**
14	1	1	1	1	1	0	1	1	1	1	1	1	1	1	**13**
D.P.	**13**	**13**	**9**	**13**	**6**	**5**	**6**	**13**	**14**	**10**	**13**	**7**	**8**	**13**	

IV. Level Partitioning

Level partitioning described the location of each driver in the digraph levels. The process began with making the reachability set for each driver that influences other drivers. For this, all those drivers were selected with whom the chosen row driver had an association with the columns. Then similarly, the antecedent set included the drivers that aid in reaching it. For this, all those drivers were taken with whom the chosen column driver was associated with the rows. Lastly, we developed the intersection set, which contained the standard drivers in the antecedent and reachability set. If a driver's reachability and intersection set turn out to be the same, that driver is considered level 1 and assigned the highest place in the I.S.M. hierarchy. Here, driver number 9- Overall, dairy farm management was found at the top of the hierarchy, which means it highly depends upon other drivers. Then the driver constituting level 1st is eliminated after the first iteration, and the technique is repeated with the remaining drivers until the levels of each driver have been determined (Table 5, Table 6, Table 7, Table 8, Table 9 and Table 10). The I.S.M. is ready to be developed after level partitioning.

Table 5 : Iteration-1

	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,3,4,8,9,10,11,12,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,4,8,10,11,12,14	
2	1,2,3,4,8,9,10,11,12,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,4,8,10,11,12,14	
3	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1,2,3,5,6,7,11,12,14	1,2,3,5,6,7,11,12,14	
4	1,2,4,8,9,11.14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,4,8,11,14	
5	1,2,3,4,5,6,7,8,9,10,11,13,14	3,5,6,7,12,14	3,5,6,7,14	
6	1,2,3,4,5,6,7,8,9,10,11,13,14	3,5,6,7,12	3,5,6,7	
7	1,2,3,4,5,6,7,8,9,10,11,12,13,14	3,5,6,7,12,14	3,5,6,7,12,14	
8	1,2,4,8,9,11,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,4,8,11,14	
9	9	1,2,3,4,5,6,7,8,9,10,11,12,13,14	9	I
10	1,2,4,8,9,10,11,13,14	1,2,3,5,6,7,10,11,12,14	1,2,10,11,14	
11	1,2,3,4,8,9,10,11,12,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,4,8,10,11,12,14	
12	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1,2,3,7,11,12,14	1,2,3,7,11,12,14	
13	1,2,4,8,9,11,13,14	3,5,6,7,10,12,13,14	13,14	
14	1,2,3,4,5,7,8,9,10,11,12,13,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,4,5,7,8,10,11,12,13,14	

Table 6 : Iteration-2

	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,3,4,8,10,11,12,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,4,8,10,11,12,14	II
2	1,2,3,4,8,10,11,12,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,4,8,10,11,12,14	II
3	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,5,6,7,11,12,14	1,2,3,5,6,7,11,12,14	
4	1,2,4,8,11.14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,4,8,11,14	II
5	1,2,3,4,5,6,7,8,10,11,13,14	3,5,6,7,12,14	3,5,6,7,14	
6	1,2,3,4,5,6,7,8,10,11,13,14	3,5,6,7,12	3,5,6,7	
7	1,2,3,4,5,6,7,8,10,11,12,13,14	3,5,6,7,12,14	3,5,6,7,12,14	
8	1,2,4,8,11,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,4,8,11,14	II
10	1,2,4,8,10,11,13,14	1,2,3,5,6,7,10,11,12,14	1,2,10,11,14	
11	1,2,3,4,8,10,11,12,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,4,8,10,11,12,14	II
12	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,7,11,12,14	1,2,3,7,11,12,14	
13	1,2,4,8,11,13,14	3,5,6,7,10,12,13,14	13,14	
14	1,2,3,4,5,7,8,10,11,12,13,14	1,2,3,4,5,6,7,8,10,11,12,13,14	1,2,3,4,5,7,8,10,11,12,13,14	II

Table 7 : Iteration-3

	Reachability Set	Antecedent Set	Intersection Set	Level
3	3,5,6,7,10,12,13	3,5,6,7,12	3,5,6,7,12	
5	3,5,6,7,10,13	3,5,6,7,12	3,5,6,7	
6	3,5,6,7,10,13	3,5,6,7,12	3,5,6,7	
7	3,5,6,7,10,12,13	3,5,6,7,12	3,5,6,7,12	
10	10,13	,3,5,6,7,11,12	10	
12	3,5,6,7,10,12,13	3,7,12	3,7,12	
13	13	3,5,6,7,10,12,13	13	III

Table 8 : Iteration-4

	Reachability Set	Antecedent Set	Intersection Set	Level
3	3,5,6,7,10,12	3,5,6,7,12	3,5,6,7,12	
5	3,5,6,7,10	3,5,6,7,12	3,5,6,7	
6	3,5,6,7,10	3,5,6,7,12	3,5,6,7	
7	3,5,6,7,10,12	3,5,6,7,12	3,5,6,7,12	
10	10	3,5,6,7,11,12	10	IV
12	3,5,6,7,10,12	3,7,12	3,7,12	

Table 9 : Iteration-5

	Reachability Set	Antecedent Set	Intersection Set	Level
3	3,5,6,7,12	3,5,6,7,12	3,5,6,7,12	V
5	3,5,6,7	3,5,6,7,12	3,5,6,7	V
6	3,5,6,7	3,5,6,7,12	3,5,6,7	V
7	3,5,6,7,12	3,5,6,7,12	3,5,6,7,12	V
12	3,5,6,7,12	3,7,12	3,7,12	

Table 10 : Iteration-6

	Reachability Set	Antecedent Set	Intersection Set	Level
12	3,5,6,7,12	3,7,12	3,7,12	VI

6.3 Developing I.S.M.

In **Error! Reference source not found.**, the six levels attained in the I.S.M. hierarchical model are given below:

- *Level I:* Overall dairy farm management
- *Level II:* Time-saving, reducing human efforts, cost control, profitability, sustainability and effective resource utilization.
- *Level III:* Improved Yield
- *Level IV:* Ease of work
- *Level V:* Quality improvement, safety/hygiene, breeding improvement and real-time monitoring
- *Level VI:* Standardised and streamlined operations

The I.S.M. model is developed as per the partition levels. The elements at the same level depict similar driving or dependence power for elements present at the above and below levels. It is evident from the digraph that 'standardized and streamlined operations at the 6th level form the base of I.S.M. It is the most significant driver of technology adoption in dairy farming that acts as the most influential driver for other drivers present at the above 5 levels. Likewise, overall dairy farm management was found at the top level 1. This means that this particular driver of technology adoption is minor driving but is most dependent upon the other drivers at the lower 5 levels.

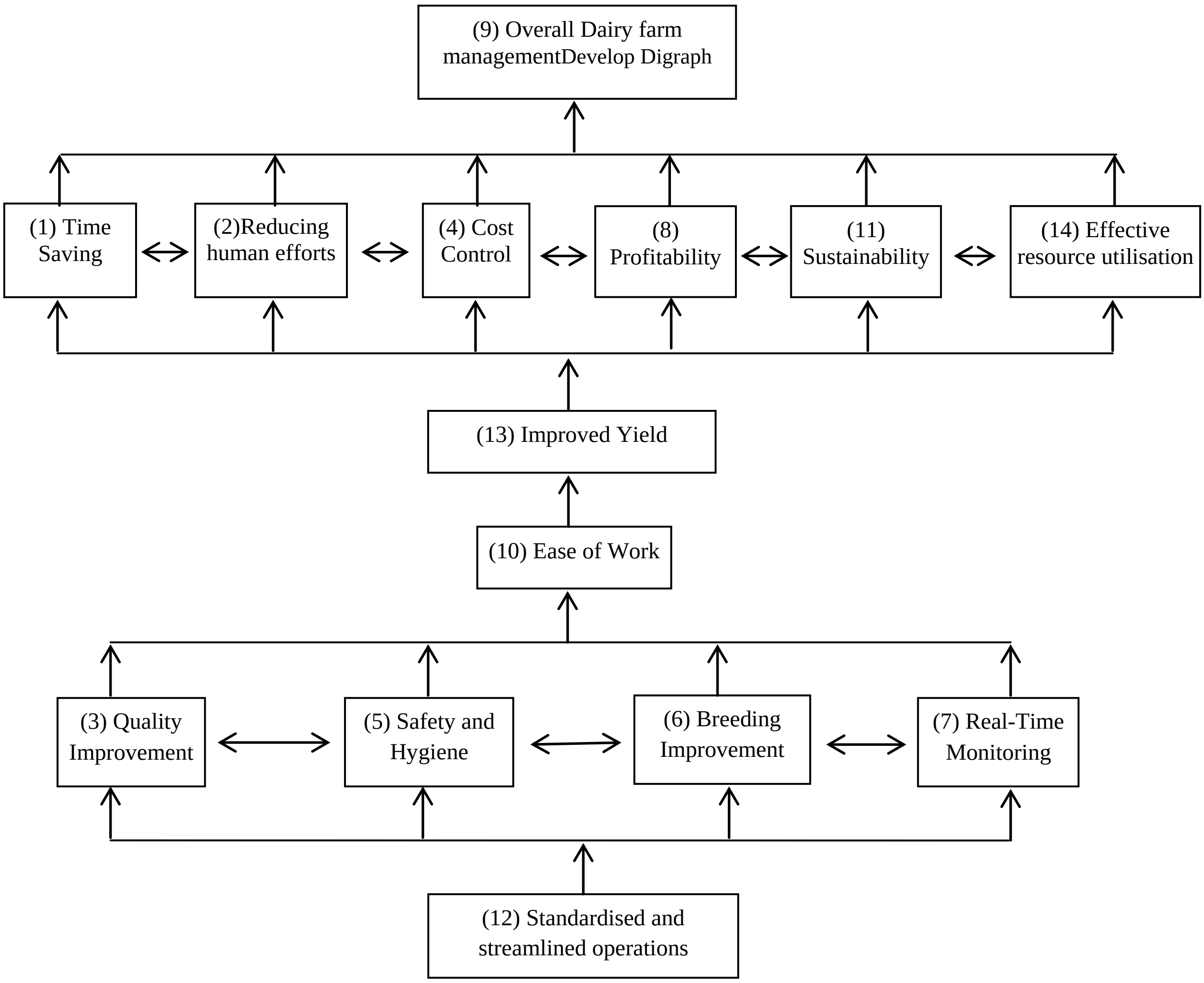

Fig. 2 : Interpretive Structural Modelling

Standardized and streamlined operations drive the elements at level V, which means that the technology adoption systematically organizes the operations and all involved activities. This leads to improvement in the overall quality, ensures hygiene and safety consideration, improvement in breeding and real-time monitoring is facilitated. All these collectively lead to easy-to-manage work at level IV. Elements at levels IV, V and VI drive yield per cattle or animal productivity improvement at level III. This can be seen as the other way round, like improvement in yield is dependent upon the elements at levels IV, V and VI.

All these collectively identified elements of technology adoption drive elements at level II- saving time, reducing human efforts, cost control, profitability, sustainability and effective resource utilization.

6.4 MICMAC

The drivers under investigation were classified using MICMAC analysis on the criteria of their driving and dependency power already computed under the final reachability matrix. The dependence and driving powers of elements are indicated in Table 11.

Table 11 : Driving and Dependence Power of Elements

Driver	Dependence Power	Driving Power
1	13	10
2	13	10
3	9	14
4	13	7
5	6	13
6	5	13
7	6	14
8	13	7
9	14	1
10	10	9
11	13	10
12	7	14
13	8	8
14	13	13

Adding up all the 1s of a chosen driver in row wise gives the driving power, and similarly, adding all the 1s of a chosen driver along with the column gives the dependence power. Thus, all 14 drivers were classified and plotted under four categories of MICMAC analysis (Fig. 3):

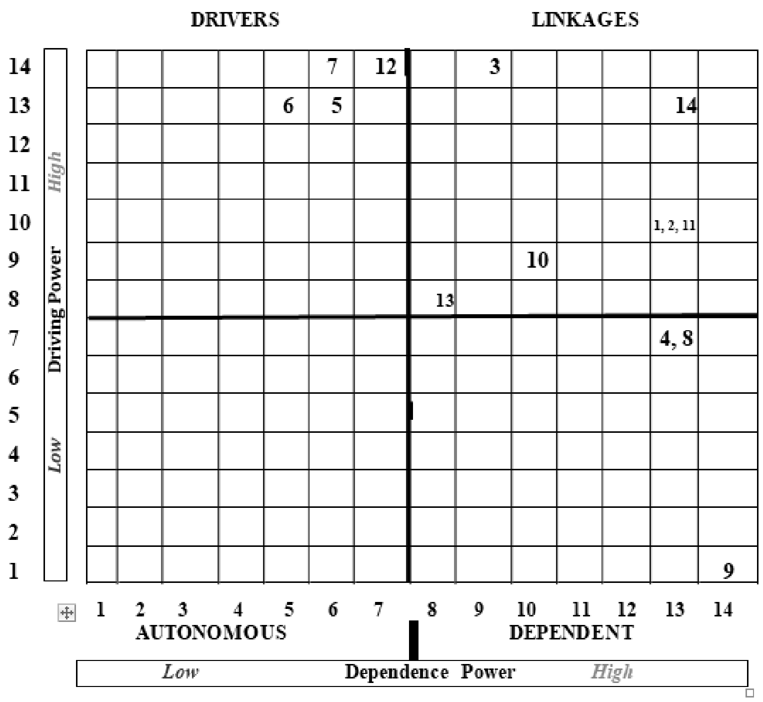

Fig. 3 : MICMAC Analysis

- *Autonomous*: These outlying elements have no significant connection with any other element. These elements have weak dependence and weak driving power.

   - No elements were found in this category.
- *Independents/Drivers*: These elements are independent means they do not depend or are relatively lesser depending upon other elements, but they attempt to drive other elements. These elements have intense driving and weak dependence on power.
   - Safety/hygiene consideration, breeding improvement, real-time monitoring and standardized and streamlined operations.
- *Dependents*: These elements are primarily dependent upon other elements. They have weak driving and strong dependence on power.
   - Cost control, profitability and overall dairy farm management.
- *Linkages*: These elements are interdependent, meaning they have strong driving and dependence power.
   - Time-saving, reducing human efforts, sustainability, effective resource utilization, improved yield, ease of work and quality improvement.

7. CONCLUSION

The objective of this research work was first to investigate such drivers in the context of Indian dairy farms that enables the technology adoption process. Secondly, to explore the relationships between the identified drivers through an ISM-based hierarchical digraph followed by an investigation of drivers' categories. The I.S.M. has provided a hierarchy of drivers to understand how drivers influence and get influenced by other drivers. Also, it has indicated the strongest driving and strongest dependent element. In this regard, standardized and streamlined operations indicated in level VI were found to be the most driving element for all other 13 elements.

Similarly, overall dairy farm management at the level I was found to be the most dependent on all other elements. Among the in-between elements, standardized and streamlined operations drive quality improvement, safety and hygiene, breeding improvement and real-time monitoring. It means that these four mentioned elements in level V are driven once technology adoption enables standardized operations. All the elements of level V further drive ease of work at level IV of I.S.M. Ease of work in operations brought along with level V and VI elements drive the improvement in yield (productivity) given at level III. Directly coming to level 1, where overall dairy farm management is marked, it can be seen that it is directly dependent upon six elements- time-saving, reduction in human efforts, cost control, profitability, effective resource utilization and sustainability. This is interpreted from bottom to top as well. Improved productivity, along with other elements of levels IV, V and VI, lead to achievement in saving time, reducing human efforts, etc., elements of level II. Managers in the dairy business can understand these drivers to improve production efficiency and business competencies and, most importantly, plan technology adoption.

To accomplish the third objective, MICMAC analysis has classified all 14 elements into four categories. No element was found to be autonomous. Standardized and streamlined operations are the strong driver, but safety and hygiene, improvement in breeding and real-time monitoring are also present in the drivers' category. Likewise, the overall dairy farm management is seen as the most dependent driver, followed by cost control and profitability. This perspective seems to be appropriate in the sense that cost control and profitability are essential for overall management. Thus, in the I.S.M., these two elements are precisely below overall dairy farm management describing the dependency. All other elements- time-saving, reducing human efforts, sustainability, effective resource utilization, improved yield, ease of work and quality improvement- were found to be interdependent or linkages. These elements are middle-of-the-road, which means they are equally dependent and driving other elements.

Finally, this research work is essential for the dairy farm owners/managers as well as academicians because any study has not yet been conducted that compares the drivers for technology adoption and their ranking in a real-time environment for Indian dairy farms to understand the rational linkage between the drivers and to plan technology adoption based on the digraph results.

8. LIMITATION

The limitation of this research work is that developing a digraph does not give any weight to the identified drivers. It could have been statistically evaluated using methods like structural equation modeling. This can be taken further as a future scope, along with constructing statistical models for various dairy supply chain interfaces

Conflicts of Interest : The authors declare no conflict of interest.

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