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BENCHMARKING THE INTERACTIONS AMONG BARRIERS IN DAIRY SUPPLY CHAIN: AN ISM APPROACH

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Abstract: *The purpose of this paper is to explore the key barriers in dairy supply chain and to analyze their interactions in the context of Indian dairy industry. A total of eight barriers have been identified through literature review and the opinions of an expert team consisting of managerial and technical experts from dairy industry and academics. A questionnaire has been developed for identified barriers and responses were collected from select dairy industries located at northern India. Interpretive structure modeling (ISM) is used to analyze the interactions among barriers and to propose a structural model. Further, the importance of barriers is determined based on their driving and dependence power using MICMAC analysis. The ISM-based model allocates to 'traceability, unbalanced production line, over-processing' as key barriers, 'wastages and high production downtime' comes next. MICMAC analysis depicts one autonomous barrier, one dependent barrier and six linkage barriers. The ISM-based model and MICMAC analysis will support the decision makers in dairy industry for planning their supply chain activities in an efficient way by managing the identified barriers.*

Keywords: *Dairy industry, barriers, supply chain, productivity, interpretive structural modeling (ISM), MICMAC analysis.*

1. Introduction

India is the largest producer of milk in the world and it is also largest consumer of milk consuming almost its whole milk production. The dairy industry in India has shaped lives of millions of dairy farmers. Dairy sector in India has been a significant contributor to the gross domestic product and its value of output has grown significantly. The dairy sector is one of the important contributors to the growth of Indian economy. The Indian dairy industry is mainly constituted of 22 state milk federations, 110,000 dairy cooperative societies involving more than 12 million milk producers. There are also some major private players in the field which further improved the dairy sector of the country namely; Amul, Britannia, Nestle, Mother Dairy, Verka, Vita, Lakshaya, Nandini etc., to name a few. The country accounts for more than 15 percent of world's total milk production and is also the world's largest consumer base of dairy products, consuming almost all of its own milk production. According to NDDB (National Dairy Development Board), 2015-16 report in India estimated milk production was

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155.49 million tonnes, which is about 6.28 percent higher than last year and estimated per capita availability was 337 grams per day, an increase of 4.7 percent over the previous year. A huge program called 'Operation Flood' was launched in India for the development of the dairy industry. It is the world's largest dairy development program was launched with the help of world food program to meet the rapidly increasing demand for milk and milk products. In the 1950's and 1960's, mass production was the adopted strategy to minimize unit production cost as the primary operations strategy, with the little flexibility in product or processes. The new product development was slow and relied exclusively on in-house technology and capacity. Efficiency and sustainability in the agri-food supply chains can be realized through innovation, supply chain collaboration, elimination of uncertainties, along with lean and green initiatives (Mor et al., 2015; 2017a; 2018a).

The technology foresight can provide an opportunity to explore the plausible future of food supply chain, especially the dairy industry sector then set to achieve that through appropriate policy initiatives. Therefore, to achieve desired future it is essential to identify the major trends, drivers, actors and factors of the dairy sector. Further, it needs to setup priority for research and development (R&D), technological transfer and diffusion, investment, sociological and political agenda, governance and trade policies. The dairy industry necessities major development in their efficiency and competitiveness status so as to meet the high quality, consistency and safety standards of the export markets (Bhardwaj et al., 2016).

Competitiveness has led the industries to implement a range of sustainable practices like local sourcing, reuse, recycling, and green purchasing (Mor et al., 2016). Authors presented the modified TOPSIS, and stated that the supply chain management emerged as manufacturers experimented with strategic partnerships with their immediate suppliers. Rahul and Kaler (2013) conducted a study to identify and eradicate the causes of poor-productivity in an automotive MNC through the Juran's problem solving technique and lean tools. Dubey et al. (2014) conducted *an* extensive review to identify research gaps, and an approach has been undertaken to further alternative methods in theory building to bridge the existing gaps using the total interpretive structural modeling.

The ISM methodology has been used to find contextual relationships among the identified Barriers in this study. ISM identifies the relationships of variables defining the problem in a graphical form and generates a visual map of the problem. ISM is available as a computer application that is easy to use and it has been applied in many areas like policy analysis, management research (Mudgal et al., 2010; Haleem et al., 2012; Govindan et al., 2013; Mathiyazhagan et al., 2013; Mathiyazhagan & Haq, 2013; Mangla et al., 2013). The methodology of ISM has a tendency to transform the undecided and inadequately expressed 'systems models' into an observable and distinct models. MICMAC theory has been used to classify the Barriers on the basis of their driving and dependence power. Diabat et al. (2013) applied the ISM approach to perform the interactions among barriers in 3PL execution, and concluded that it is advantageous for the management of an enterprise to be aware of the barriers and to identify them for the organization's future survival. Quality management in supply chains needs commitment at all levels of the organization by providing the possible benefits like customer satisfaction, enhanced productivity and business competitiveness (Gunasekaran, 1999). Poor logistics and transportation facilities is the most critical factor as productivity barrier in dairy industry (Mor et al., 2017b).

This study is an attempt to establish contextual relationship between various Barriers in the dairy industry. Both private and cooperative dairy industries located in the northern region of India are considered. Initially, fifteen Barriers were diagnosed, but only eleven Barriers have been finalized for further analysis on the basis of the relevant literature available and the recommendations of an expert team consisting of managerial experts from the dairy industry and academicians. Studying and analyzing the interactions among different Barriers and applying the ISM methodology, this paper seeks to establish the following contributions:

- First, an ISM hierarchical model is developed. This model provides the importance of the Barriers in the supply chain practices in dairy industry. Based on the importance, dairy representatives can prepare the plan their resources to utilize optimally.
- Second, with the help of ISM-based model, an impact matrix cross-reference multiplication applied to a classification (MICMAC) analysis is prepared. This analysis indicates that there are no identified independent barrier(s).

The outcome of this study may prove to be useful for the dairy industry sector to execute an efficient and sustainable supply chain practices. ISM based model and the MICMAC analysis may be considered major contributions to this research work. Thus, the present research fundamentally concentrates on the barriers causing low-productivity in dairy supply chain using ISM techniques. The rest of paper is prepared as follows. Section 2 consists of literature review part, and section 3 is problem description. Section 4 discusses the research methodology, while, section 6 is the application of ISM methodology to the study undertaken. The analysis and results are given in section 6, and section 7 is the managerial implications of study. Section 8 contains the conclusion, limitation and future scope of the study.

2. Literature review

Quality management appears to be the most significant factor followed by inventory management, supplier management and technological innovations in dairy industry (Mor et al., 2018b). Mangla et al. (2016) suggested that for achieving success in food supply chain, it is needed to focus on critical success factors that are necessary for an organization to improve its performance. Chalúpková et al. (2014) found that decision making can be performed according to perspectives that may also be conflicting in nature. Ayodele et al. (2014) identified the key research challenges in unpacking and knowledge optimization strategies and their effectiveness in practice, especially when considering the end consumer knowledge, preferences, and behavior can be incorporated in food chains. Okano et al. (2014) proposed that it is possible to organize the estates of the dairy chain, using indicators to rank them, modeling best practices to improve productivity and become a sustainable productive chain. Bharti (2014) worked on the potential as well as the challenges and staggering losses in the frozen food sector due to ill-equipped and weak cold chain infrastructure of the country ensuing post-harvest losses in the frozen food business in India. Lemma et al. (2014) presented the modeling and optimization approaches used in perishable food supply chain literature, focusing not only the perishability of products but also the waste and loss assessment in food supply chain, through modeling and optimization tools. Nicholas et al. (2014) applied the Q methodology to determine the attitudes of low input and organic dairy supply chain members in four European countries to the acceptability of various innovations in dairy farm and dairy supply chain practices. Ghosh et al. (2014) studied the dairy industry where both dairy farming industry and dairy processing industry suffers a lot of risks in its functioning and analyzed various enablers of risk management involved in the dairy sector with the help of interpretive structural modeling (ISM) tool. Patel et al. (2014) argued that the product development that does not occur in isolation as a separate functional activity, rather it is a basic company strategy. Kumar (2014) aimed to evaluate the usefulness of a novel conceptual model for supply chain performance measurement in a dairy supply chain and proposed a conceptual model. Prakash and Pant (2013) presented a case of the Indian dairy supply chain and demonstrated how balanced score card (BSC) approach may be used to measure its performance. Prasad and Satsangi (2013) examined the relationship between designs of an organization with its operational efficiency indicators in the context of Amul and found that the design of the basic structure is somewhat different as it believes in the federal form of structure each unit is independent of each other. Kumar et al. (2012) explored the conceptualization and implementation of geographical information system (GIS) for dairy industry to assess the milk procurement potential, and concluded that the tools like GIS and its analytical applications like proximity analysis, buffering help in taking business decisions like tapping new villages as procurement centers. Gupta and Roy (2012) provided an assessment of benefits to farmers from vertical coordination in dairy in Punjab, through regression analyses and field survey to quantify the benefits. Mishra and Shekhar (2011) outlined the uncertainties and their impact at various stages of the supply chain along with their impact in the dairy industry. Kumar et al. (2011) concluded that the modern milk supply chain seems to have an inclusive structure and the resource-poor dairy farmers are not excluded from the modern milk supply chain. Mor et al. (2018a; 2018b) show that the higher competence in food processing sector is the result of supply chains devoted towards high product quality, on-time delivery of processed products and better order-fill-rate.

3. Problem description

After comprehensive literature review, it has been realized that the researches in the area of dairy sector are limited and does not take into account the supply chain practices, especially in Indian context. Also, the existing studies are emphasized on proposing support to the farmers and linking them up with urban markets. But no study yet relates the productivity barriers in dairy industry (in the industrial context), and their interactions. Hence, this research study is an attempts to address the barriers causing low-productivity in dairy industry and their interactions by presenting an ISM model.

3.1. Objectives of study

- To bring out the barriers in dairy supply chain.
- Establishing the interactions among barriers in dairy industry through an ISM-based model and classifying the barriers through MICMAC analysis.

3.2. Identification of barriers

In present work, eight barriers have been identified as variables. Authors designed a survey questionnaire and circulated among experts to confirm the identified barriers in context to the dairy industry. The first objective of this study is fulfilled with the identification of barriers. The identified barriers are explained below (Table 1).

Thus, authors have worked on dairy supply chain analysis globally. A brief has been drawn from the past studies and the pilot studies conducted for dairy supply chain analysis in the current research study. All the identified barrier are listed in Table 1 along with their source/reference.

Table 1. Identification of barriers

Sr. No	Barriers	Description	Reference
1	Wastage due to leakages at shop-floor	Wastages in milk processing plant occurs in the form of water, steam and milk due to leakages and unsealed packaging. Wastages in an industry leads to reduced productivity and high product cost.	Singh et al. (2013); FAO Project; Singh et al. (2015); Bhanpurkar et al. (2012); Rahul and Kaler (2013)
2	High production downtime	High production downtime in milk processing plant occurs due to frequent machinery breakdowns, power failures, poor maintenance of machinery and conveyor etc.	Shagluf et al. (2014); Christer and Waller (1984); Davim (2016)
3	Lack of automation and outdated technology	Today's dairy plants needs to be modernized so as to compete globally. This can happen only with the process automation and implementation of latest technology in the production process.	Harting (2016); Mor et al. (2017a; 2018a) Expert opinion
4	Traceability of 'machinery breakdown and quality issues'	Another major issues involves 'no provision for traceability of machinery breakdown and quality issues'. The traceability of milk quality issues is major factor for dairy industry as this reduces various non-value-adding (NVA) activities due to sampling and testing of milk.	Pant et al. (2015); Beske et al. (2014); Apte (2010); Expert opinion
5	Unbalanced production line	The unbalanced production line is next major concern in dairy industry. Milk pouches from machine are stored in a tray and there exists two operators on each workstation who are responsible to put the milk pouch in bin/crate which are moving along with the conveyor chain.	Rahul and Kaler (2013); El-Rayah (1979); Sadowski and Medeiros (1979); Lopez (2014); Shaaban et al. (2013); Hudson et al. (2016); Iskander and Chou. (1990)
6	Over processing and operator's negligence	Another issue in milk processing is the over-processing of milk and milk products. The wasted milk due to leakages is again processed and packaged into pouches which is 'Muri' and needs to be eliminated through proper machinery maintenance and automatic product packaging line.	Islam et al. (2016); Rahul and Kaler (2013); Vijayakumar, Robinson (2016); Arunagiri and Babu (2013)
7	Improper demand forecast	For the products with short life cycle, the accuracy of the forecast is of crucial importance because of the volatile demand pattern, influenced by an environment of rapid and dynamic response. It is found missing in dairy industry.	Hassan et al. (2015); Zhou et al. (2015); Sugiarto et al. (2016); Expert opinion
8	More waiting time at milk packaging line	More waiting time at milk packaging line. The packaging technology of products needs to be updated and well maintained for faster packing of material. Use of belt conveyers and automated milk packaging machines is necessary.	Yam (2010); Mor et al. (2015; 2016) Expert opinion

4. Methodology

An interpretive structural modeling (ISM) approach is used in current research work as a solution methodology. It helps to understand the contextual relationships among barriers, their interdependence and finally to implement the effective supply chain practices in the dairy industry. The ISM methodology followed by MICMAC analysis is discussed below.

4.1. Interpretive Structural Modeling (ISM)

The ISM methodology was primarily offered by Prof. J. Warfield to study complex socio-economic systems. ISM can be used as a systematic way to recognize contextual relations among measured elements associated with a problem to be explored (Warfield, 1974). ISM approach is mainly proposed as a group learning process, but can also be used exclusively. ISM transforms the uncertain system models into a precise model. ISM is used for a methodical thinking approach, and this offers way for various complex relations among variables (Jharkharia & Shankar, 2004). ISM tests for grouping the expert opinion by supporting various methods like nominal technique, brain-storming, and affinity diagramming in making the contextual relationships among variables (Ravi & Shankar, 2005).

The key limitation of ISM contain the unfairness of the expert who is determining the variables affecting the final model (Kannan & Haq, 2006). Further, ISM does not offer any weightage to the variables as well. ISM can be described in the following steps, for the current study (Figure 1), as suggested by Haleem et al., 2012; Mangla et al., 2013:

- In the first step, elements or barriers under study are listed.
- In next step, the barriers are operated to prepare a Structural Self-Interaction Matrix (SSIM). It offered the contextual relations among the barriers under study.
- The SSIM is made to develop an initial reachability matrix.
- Then, the developed matrix is checked for transitive relations so as to develop the final reachability matrix. The transitive relations mean that if an element ‘X’ is related to element ‘Y’ and element ‘Y’ is related to element ‘Z’, then element ‘X’ is certainly related to element ‘Z’.
- In next step, partitioning the reachability matrix into different hierarchical levels are completed.
- The digraph are drawn by using the contextual relations recognized in the reachability matrix.
- The transitive relations are removed by replacing the element nodes with problem statements/elements to convert the directed digraph into an ISM model (Figure 1).
- The conceptual inconsistency of model is tested and improved for the corrections.

4.2. MICMAC Analysis

Matrice d'Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) was developed by Duperrin and Godet (1973). It is generally known as Cross-Impact Matrix Multiplication Applied to Classification. MICMAC analysis comprises of developing a graph to classify the variables under study based on their driving and dependence power. MICMAC analysis is used to classify the barriers and validate the interpretive structural model of identified barriers in the current study.

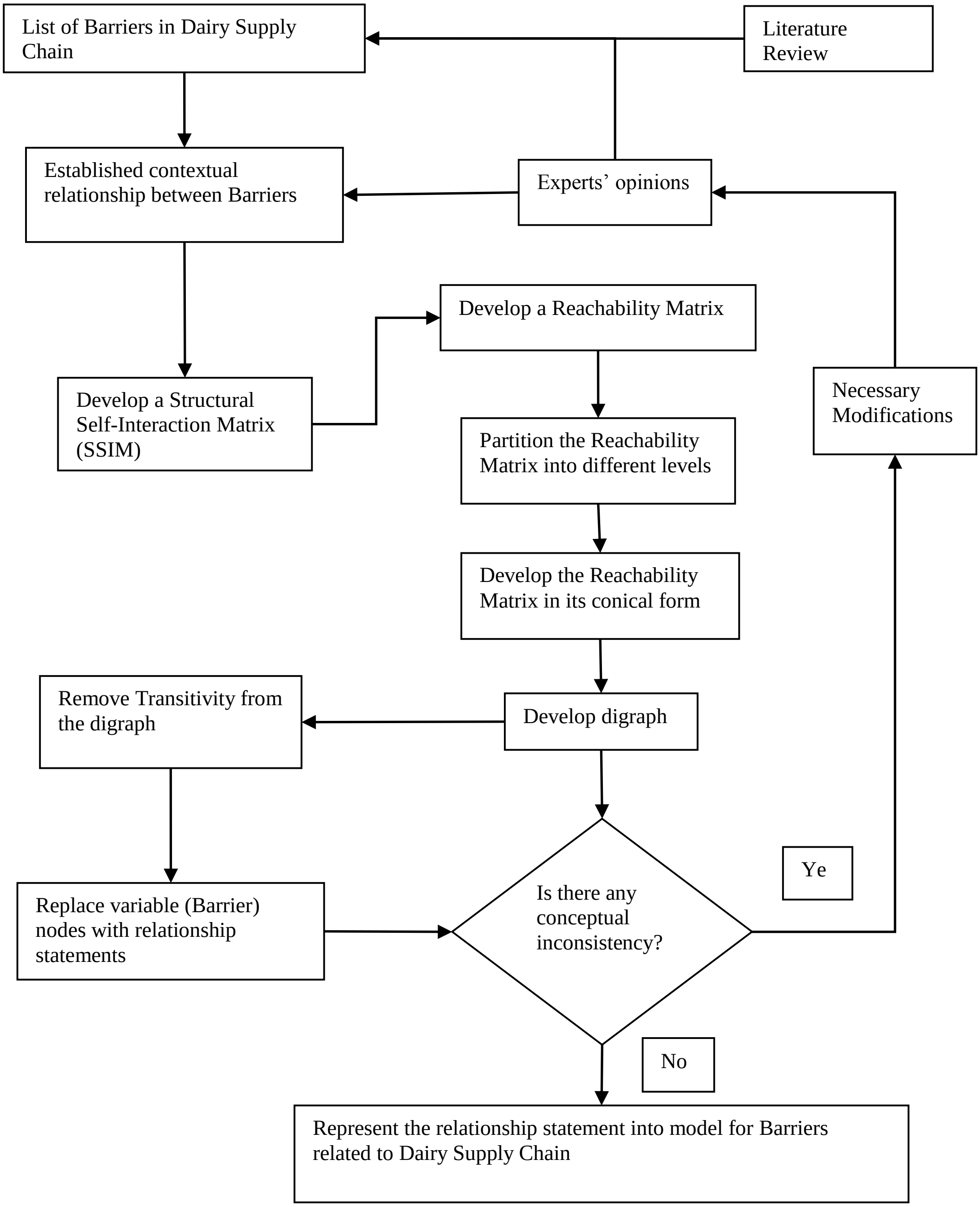

Figure 1. ISM Methodology for analyzing Barriers

5. Application to the Case illustration

The current study has been divided into two key groups. First group involved the participants as experts from academics and research in the field of operations and supply chain management. Second group involved of the individuals linked directly with dairy supply chain practices based in the northern India. Finally, the experts from academics and the industry people were communicated to secure respondents for the pilot portion of this study. The data has been collected by a predesigned questionnaire and personal visits to the selected dairy industries. Given below are the steps to evaluate the collected data:

5.1. Development of Structural Self-Interaction Matrix (SSIM)

Next step is to build a self-structured interaction matrix based on the interaction between identified barriers. The experts were asked to scale the identified barriers on a five point Likert scale (1= Extremely Insignificant, 5= Extremely Significant). Based on the feedback received from respondents, all the eight barriers for dairy industry have been fixed. ISM approach depends on the expert opinion for developing self-structured interaction matrix (SSIM). After finding the barriers for case industry, the contextual relations among barriers have been made with the discussion of decision team of eight professionals. For this an SSIM matrix has been made for barriers (Table 2), following four symbols utilized to specify the direction of relation between two barriers (say *i* and *j*).

- V- Barrier B *i* will facilitate to reach B *j*;
- A- B *j* will facilitate to reach B *i*;
- X- B *i* and *j* will facilitate to reach each other; and
- O- B *i* and *j* are unrelated.

Table 2. Self-Structured Interaction Matrix for Barriers

Sr. No.	Barriers	8	7	6	5	4	3	2
1	Wastage due to leakages at shop-floor	A	A	O	X	O	X	O
2	High production downtime	A	O	V	O	V	O	
3	Lack of automation and outdated technology	O	V	O	O	A		
4	Traceability of 'machinery breakdown and quality issues'	X	V	V	O			
5	Unbalanced production line	A	A	O				
6	Over processing and operator's negligence	A	X					
7	Improper demand forecast	O						
8	More waiting time at milk packaging line							

5.2. Formation of Reachability Matrix

Here, the SSIM is converted into an Initial Reachability Matrix. It is a binary matrix containing 0 and 1 (Table 3), and following directions are followed:

- For every V (i.e. at any (*i*, *j*)) in the SSIM, the reachability matrix have 1 for (*i*, *j*) and 0 for (*j*, *i*);
- For every A (i.e. at any (*i*, *j*)) in the SSIM, the reachability matrix have 0 for (*i*, *j*) and 1 for (*j*, *i*);
- For every X (i.e. at any (*i*, *j*)) in the SSIM, the reachability matrix have 1 for (*i*, *j*) and 1 for (*j*, *i*);
- For every O (i.e. at any (*i*, *j*)) in the SSIM, the reachability matrix have 0 for (*i*, *j*) and 0 for (*j*, *i*).

Following the ISM instructions, authors get the initial reachability matrix (Table 3). This matrix transforms the interactions among barriers into binary coding form (1 and 0).

Table 3. Initial Reachability Matrix for Barriers

Sr. No.	Barriers	1	2	3	4	5	6	7	8
1	Wastage due to leakages at shop-floor	1	0	1	0	1	0	0	0
2	High production downtime	0	1	0	1	0	1	0	0
3	Lack of automation and outdated technology	1	0	1	0	0	0	1	0
4	Traceability of 'machinery breakdown and quality issues'	0	0	1	1	0	1	1	1
5	Unbalanced production line	1	0	0	0	1	0	0	0
6	Over processing and operator's negligence	0	0	0	0	0	1	1	0
7	Improper demand forecast	1	0	0	0	1	1	1	0
8	More waiting time at milk packaging line	1	1	0	1	1	1	0	1

In next step, the initial reachability matrix is transformed into final reachability matrix. The final reachability matrix is built by considering the rule of transitivity, as discussed above. The final reachability matrix is presented in (Table 4). The star marked values specifies that the particular interaction(s) got value as '1' after considering the transitivity rules.

Table 4. Final Reachability Matrix for Barriers

Sr. No.	Barriers	1	2	3	4	5	6	7	8	*Driving Power*
1	Wastage due to leakages at shop-floor	1	0	1	1*	1	0	1*	1*	***6***
2	High production downtime	0	1	0	1	0	1	0	0	***3***
3	Lack of automation and outdated technology	1	0	1	1*	1*	1*	1	1*	***7***
4	Traceability of 'machinery breakdown and quality issues'	1*	1*	1	1	0	1	1	1	***7***
5	Unbalanced production line	1	0	1*	0	1	0	1*	1*	***5***
6	Over processing and operator's negligence	0	0	1*	1*	0	1	1	0	***4***
7	Improper demand forecast	1	1*	1*	1*	1	1	1	1*	***8***
8	More waiting time at milk packaging line	1	1	1*	1	1	1	1*	1	***8***
Dependence Power		***6***	***4***	***7***	***7***	***5***	***6***	***7***	***6***	

* *indicates the values after applying Transitivity*

Next, the final reachability matrix is built from initial reachability matrix as shown in Table 4. It incorporates the transitive relations among the barriers. Then, driving and dependence power has been calculated for each barrier. The barriers with serial number as 2, 5, and 6 (i.e. High production downtime, Unbalanced production line, and Over processing and operator's negligence) have been observed the lowest driving power. While, the barriers with serial number as 3, 4, 7, and 8 (i.e. Lack of automation and outdated technology, Traceability of 'machinery breakdown and quality issues', Improper demand forecast, and More waiting time at milk packaging line) has observed highest driving power. The calculated driving and dependence power of the barriers will be used as an input for MICMAC analysis for classifying the barriers based upon their driving and dependence power. Further, the Reachability set, Antecedent set, and Intersection sets have been identified and partitioning of levels has been done in the Table 5.

5.3. Level partitioning

The reachability set for an individual barrier is comprised of the barrier and the other barriers which it may support to reach. The antecedent set involve the barrier themselves and the other barriers which may support in reaching it. The relation of both these sets was also derived for all barriers (Table 5). If the reachability set and the intersection set for a given barrier are the same, then that barrier is considered to be in level 1 and is allocated as the highest position in the ISM hierarchy. After first iteration, the barriers forming level 1st are discarded, and the above stated procedure is continued with the remaining barriers until the levels of each barrier have been found (Table 5).

Table 5. Level Partitioning Matrix for Barriers

Sr. No.	Barriers	Reachability Set	Antecend Set	Intersection Set	Level
1	Wastage due to leakages at shop-floor	1, 3, 4, 5, 7, 8	1, 3, 5, 7, 8	1, 3, 5, 7, 8	
2	High production downtime	2, 4, 6	2, 8	2	
3	Lack of automation and outdated technology	1, 3, 4, 6, 7, 8	1, 3, 4, 5, 6, 8	1, 3, 4, 5, 6, 8	
4	Traceability of 'machinery breakdown and quality issues'	1, 2, 3, 4, 6, 7, 8	1, 2, 3, 4, 6, 7, 8	1, 2, 3, 4, 6, 7, 8	I
5	Unbalanced production line	1, 3, 5, 7, 8	1, 3, 5, 7, 8	1, 3, 5, 7, 8	I
6	Over processing and operator's negligence	3, 4, 6, 7	2, 3, 4, 6, 7, 8	3, 4, 6, 7	I
7	Improper demand forecast	1, 2, 3, 4, 5, 6, 7, 8	1, 3, 4, 5, 6, 7, 8	1, 3, 4, 5, 6, 7, 8	
8	More waiting time at milk packaging line	1, 2, 3, 4, 5, 6, 7, 8	1, 3, 4, 5, 7, 8	1, 3, 4, 5, 7, 8	

The final level of each barrier is shown in Table 6. Three barriers with serial number 4, 5, and 6 (i.e. Traceability of 'machinery breakdown and quality issues', Unbalanced production line, and Over processing and operator's negligence) have been found the top (1st) level and it will be assigned to top of the ISM hierarchy. Two barriers with serial number 1, and 2 (i.e. Wastage due to leakages at shop-floor, and High production downtime) have been found (2th) level. Two barriers with serial number 7, and 8 (i.e. Improper demand forecast, and More waiting time at milk packaging line) have been found (3rd) level. Finally, one barrier with serial number 3 (i.e. Lack of automation and outdated technology) have been found last (4th) level and will be assigned to bottom of the ISM hierarchy. Development of ISM based model 'Lack of automation and outdated technology, Traceability of 'machinery breakdown and quality issues', Improper demand forecast, and More waiting time at milk packaging line' has been recognized most driving barriers in Table 4. Similarly, the 'Lack of automation and outdated technology, Traceability of 'machinery breakdown and quality issues, and Improper demand forecast' have been found most dependent barriers in Table 4. Four levels have been identified from level partitioning in Table 6.

Table 6. Level Partitioning for all Barriers

All Levels		
Sr. No.	**Level**	**Barriers**
1	I	Traceability of 'machinery breakdown and quality issues'
2		Unbalanced production line
3		Over processing and operator's negligence
4	II	Wastage due to leakages at shop-floor
5		High production downtime
6	III	Improper demand forecast
7		More waiting time at milk packaging line
8	IV	Lack of automation and outdated technology

From the final reachability matrix (Table 4) and final levels of barriers (Table 6), a hierarchical structural model of the various barriers causing low-productivity in dairy industry has been developed and is shown in Figure 2.

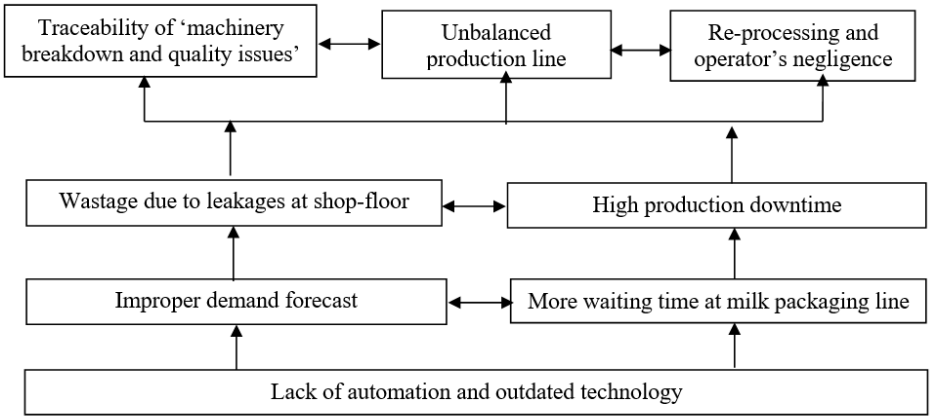

Figure 2. Interpretive Structural Model of Barriers

The levels achieved in ISM hierarchical model are described below.

1) Level - 1: The three barriers i.e. Traceability of 'machinery breakdown and quality issues', Unbalanced production line , and Over processing and operator's negligence stands in the first level, as per the outcomes of ISM hierarchical model.
2) Level - 2: The two barriers i.e. Wastage due to leakages at shop-floor, and High production downtime stands on the second level, as per the outcomes of ISM hierarchical model.
3) Level - 3: Improper demand forecast, and more waiting time at milk packaging line plays an important role in production performance and stands on the third level, as per the outcomes of ISM hierarchical model.
4) Level - 4: This level consists of one barrier i.e. Lack of automation and outdated technology, as per the outcomes of ISM hierarchical model.

After getting the ISM levels, the MICMAC analysis has also been performed to classify identified barriers, as follows.

5.4. ISM Model

From the level partitions (Table 6), the ISM model is developed as shown in Figure 2. It is perceived from ISM model that the barrier 'Lack of automation and outdated technology' stands at level 4 and is very significant barriers in dairy industry as they form the base of ISM-based hierarchical model (Table 6).

5.4. MICMAC Analysis: Classification of Barriers

MICMAC i.e. Matrice d'Impacts Croisés Multiplication Appliquée á un Classement was developed by Duperrin and Godet (1973). Commonly known as Cross-Impact Matrix Multiplication Applied to Classification, MICMAC analysis consist of developing a graph to classify the identified elements i.e. barriers for benchmarking the dairy supply chains based on their driving and dependence power, in this case. For further analysis of barriers in current study, MICMAC analysis has been performed to classify the barriers under study based on their driving and dependence power. Though the driving power and dependence power of every variable are calculated by using the final reachability matrix. Driving power means an activity impelling to other activities, and dependence power means an activity impelled by other activities. The driving and dependence power is calculated from final reachability matrix by considering the numbers sum of all '1's in the corresponding row and column of that barrier as the driving and dependence power. This is considered as an input to build a graph to classify the barriers. It is done so as to evaluate the dairy supply chains into four regions i.e. Autonomous, Dependent, Linkage, and Independent barriers. Autonomous barriers (first region) have weak driving power and weak dependence power. Dependent barriers (second region) have weak driving power and strong dependence power. Linkage barriers (third region) have strong driving power and strong dependence power. In the dependent barriers (fourth region) acquires strong driving power and weak dependence power. The corresponding powers of barriers are shown in Table 7.

Table 7. Power based ranking of Barriers

Sr. No.	Barriers	Driving power	Driving based rank	Dependence power	Dependence based rank
1	Wastage due to leakages at shop-floor	6	III	6	II
2	High production downtime	3	VI	3	IV
3	Lack of automation and outdated technology	7	II	7	I
4	Traceability of 'machinery breakdown and quality issues'	7	II	7	I
5	Unbalanced production line	5	IV	5	III
6	Over processing and operator's negligence	4	V	6	II
7	Improper demand forecast	8	I	7	I
8	More waiting time at milk packaging line	8	I	6	II

All the barriers can be divided into four quadrants, as per their driving and dependence power. The barriers with their respective activities are shown in Table 8, below.

Table 8. Grouping of Barriers according to the Driving and Dependence Power

Quadrant No.	Name of Elements	Driving Power	Dependence Power	Barriers
I	Autonomous	Weak	Weak	High production downtime
II	Dependent	Weak	Strong	Over processing and operator's negligence
III	Linkage	Strong	Strong	Wastage due to leakages at shop-floor Lack of automation and outdated technology Traceability of 'machinery breakdown and quality issues' Unbalanced production line Improper demand forecast More waiting time at milk packaging line
IV	Driver or independent	Strong	Weak	

In this study, there is no independent activity or barrier. Linkage barriers are having the high driving and high dependence power, but are uneven in nature because any action on these barriers will affect the others and also feedback on themselves. Using the MICMAC analysis, a driving power and dependence power diagram for barriers is plotted in Figure 3.

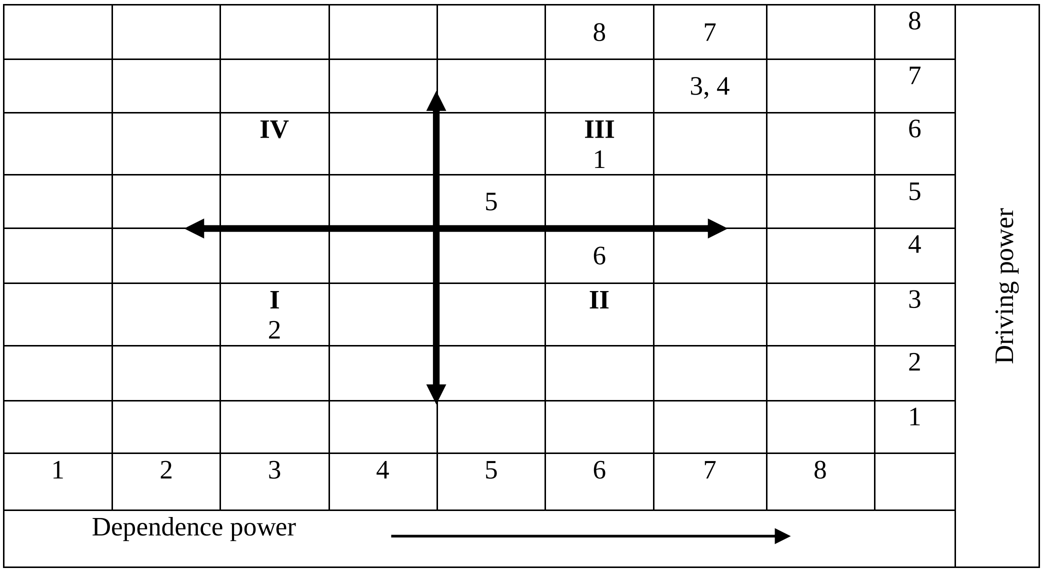

Figure 3. MICMAC Analysis of Barriers

Figure 3 shows the diagram between dependence power and driving power for the barriers important to evaluate the dairy supply chain.

6. Results and Discussion

The objective of this research study is to first, explore the barriers in case of Indian dairy industry, and second, to benchmark the relations among the identified barriers. An ISM-based hierarchical model has been developed to examine the importance of barriers in evaluating the dairy supply chain. The ISM model offers a hierarchy of actions to be taken to manage the identified barriers effectively for better supply chain performance. The managers in dairy industry can get an insight into these barriers so as to get higher production efficiency and business competences. The observations from the proposed ISM-based model is that four barriers are at the level- I and form the top ISM hierarchy. These barriers have an average driving power, but higher dependence power. The rest of the barriers are classified on different levels as follows:

1) Level- 1: The three barriers i.e. Traceability of 'machinery breakdown and quality issues', Unbalanced production line , and Over processing and operator's negligence stands in the first level, as per the outcomes of ISM hierarchical model.
2) Level- 2: The two barriers i.e. Wastage due to leakages at shop-floor, and High production downtime stands on the second level, as per the outcomes of ISM hierarchical model.
3) Level- 3: Improper demand forecast, and more waiting time at milk packaging line plays an important role in production performance and stands on the third level, as per the outcomes of ISM hierarchical model.
4) Level- 4: This level consists of one barrier i.e. Lack of automation and outdated technology, as per the outcomes of ISM hierarchical model.

Finally, level 4 forms the base of the ISM hierarchy and can be considered as least important Barrier for the production performance in dairy industry. These barriers have the high driving power and low dependence power; hence, they form the bottom level of the hierarchy. By performing MICMAC analysis, the driver-dependence diagram is plotted which offers information about the relative significance and the interdependencies among various barriers in dairy supply chains. From the Figure 3, it is found that in this study, there exists no independent barrier. Among the eight barriers studied in this paper, one barrier is falling in dependent quadrant in the dependence-driver diagram and it is recognized that this particular barrier will depend on other barriers. Further, one barrier falls under the autonomous quadrant which needs to be analysed by immediately the dairy managers. Rest six barriers falls under the linkage quadrant which uneven and specifies high driving power as well as the high dependence power.

7. Managerial implications

ISM methodology assists the managers to establish a map of the complex relations between various elements in decision-making process. The theoretical implication of the ISM approach is that it can clarify a complex systems into a hierarchical model with multiple levels. Its practical implication contains to make use of the decision makers' knowledge so as to provide a fundamental understanding of a complex situation, followed by a course of action for problem-solving. Using the proposed model in this study, the decision makers in dairy supply industry can plan their supply chain activities to eradicate the barriers, proceed with the necessary actions to manage them effectively, and gain the competitive advantage over competitors in the supply chain. The MICMAC analysis shows that there is no independent barrier in evaluating the dairy supply chain.

8. Conclusions

Dairy industry is strongly affected by high level of wastages, poor cold chain infrastructure, and poor information systems. More wastages happen due to multiple points of milk handling manually. After comprehensive literature review and the consultation with the expert team, eight barriers to evaluate the dairy supply chain have been identified. The insights from ISM-based model is that the barrier 'Traceability of machinery breakdown and quality issues', Unbalanced production line , and Over processing and operator's negligence' are at level 1 and located at top of the ISM hierarchy. These barriers have strong dependence and weak driving power. Similarly, the remaining barriers have been found at different levels and finally, the 'Lack of automation and outdated technology' form the base of ISM-based model. The base barriers requires more attention by the decision makers in dairy industry. Thus, the dairy industries need significant improvement in their operations management, technological innovations, information systems, wastages management as well as the responsiveness of machine operator followed by effective traceability systems. The complexity emerging from the uniqueness of dairy supply chain, especially in the Indian cooperative dairy system that runs on three tier Anand pattern, also requires an incentive or year round remuneration system so as to improve the overall productivity of dairy industry.

A comparison can be made among previous studies in this context. Authors such as Mor et al. (2016), Mor et al. (2017a; 2017b), Rahul and Kaler (2013) etc. have diagnosed the productivity barriers and critical factors (CFs) in different areas but these studies do not suggest any ranking among identified barriers/CFs, as in this case. Current study strengthen the findings of Mor et al. (2015), Mor et al. (2018a; 2018b), Rahul and Kaler (2013) by offering a ranking. Further, ISM methodology has diverse applications as suggested by Mangla et al. (2016), Haleem et al. (2012), Diabat et al. (2013), Dubey et al. (2014), Prakash and Pant (2013), Mathiyazhagan et al. (2013), Govindan et al. (2013) etc. and the current study is an attempt to generalize the application of ISM to benchmark the interactions among supply chain practices in dairy industry.

Finally, this study is significant for dairy industry sector as well as for academics because no study yet relate the barriers and their ranking in a real-time industrial scenario for Indian dairy industry sector. Moreover, an emphasis on infrastructural development, effective production processes and information system highlighted in this work can assist the managers and professionals to achieve long-term corporate goals of dairy industry.

8.1. Limitations of study and directions for future research

The limitation of this this study is that the model assign any weightage to the selected barriers and it has to be validated statistically with tools like structural equation modeling as a plan for future research work. Further, this methodology may be generalized for other perishable food processing industries such as meat, bakery, poultry, fishery etc. Future research studies can be conducted on developing statistical models for various interfaces of dairy supply chain.

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References:

Arunagiri, P., & Babu, A. G. (2013). Review on reduction of delay in manufacturing process using lean six sigma system. *International Journal of Scientific and Research Publications*, *3*(2), 1-4.

Ayodele, A. B., Ellis, L., & Turner, P. (2014). Identifying key research challenges in investigating knowledge optimization strategies in perishable food chains. *11th Int. Conf. on Intellectual Capital, Knowledge Management and Organisational Learning*, University of Sydney, Australia.

Bhanpurkar, A., Bangar, A., Goyal, S., & Agrawal, P. (2012). Implementation of six sigma program for lean manufacturing to reduce the rework waste in transformer manufacturing unit by eliminating defect of leakage from bushings in oil filled transformers. *International Journal of Mechanical and Industrial Engineering*, *1*(3), 6-11.

Bhardwaj, A., Mor, R. S., Singh, S., & Dev, M. (2016). An investigation into the dynamics of supply chain practices in Dairy industry: a pilot study. *Proceedings of the 2016 International Conference on Industrial Engineering and Operations Management*, Detroit, Michigan, USA, Sept. 23-25, 2016, 1360-1365.

Bharti, A. (2014). Examining market challenges pertaining to cold chain in the frozen food industry in Indian retail sector. *Apeejay Journal of Management Sciences and Technology*, *2*(1), 33-40.

Chalúpková, E., & Franek, J. (2014). Application of the analytic hierarchy process method in a comparison of financial leasing and loans. *Ekonomická Revue- Central European Review of Economic Issues*, *17*, 75-84.

Christer, A. H., & Waller, W. M. (1984). Reducing production downtime using delay-time analysis. *Journal of the Operational Research Society*, *35*(6), 499-512.

Davim, J. P. (2016). *Metal Cutting Technologies: Progress and Current Trends*. Walter de Gruyter GmbH and Co KG.

Diabat, A., Khreishahh, A., Kanan, G., Panikar, V., & Gunasekaran, A. (2013). Benchmarking the interactions among barriers in third-party logistics implementation: an ISM approach. *Benchmarking: An International Journal*, *20*(6), 805-824.

Dubey, R., Gunasekaran, A., Sushil, & Singh, T. (2014). Building theory of sustainable manufacturing using total interpretive structural modeling. *International Journal of Systems Science: Operations and Logistics*, *2*(4), 231-247.

Duperrin, J. C., & Godet, M. (1973). Matrice d'Impacts Croisés Multiplication Appliquée á un Classement. *Rapp. Econ. CEA*, 45-51.

El-Rayah, L. (1979). The efficiency of balanced and unbalanced production lines. *International Journal of Production Research*, *17*(1), 61-75.

Ghosh, A., Sindhu, S., Panghal, A., & Bhayana, S. (2014). Modeling the enablers for risk management in milk processing industry. *International Journal of Management and International Business Studies*, *4*(1), 9-16.

Govindan, K., Kannan, D., Mathiyazhagan, K., Jabbour, A. B., & Jabbour, C. J. (2013). Analyzing green supply chain management practices in Brazil's electrical/electronics industry using interpretive structural modeling. *International Journal of Environmental Studies*, 1-17.

Gunasekaran, A. (1999). Enablers of total quality management implementation on manufacturing: a case study. *Total Quality Management*, *10*(7), 987996.

Gupta, K., & Roy, D. (2012). Gains from coordination in MilkFed dairy in Punjab. *Journal of Agribusiness in Developing and Emerging Economies*, *2*(2), 92-114.

Haleem, A., Sushil, Qadri, M. A., & Kumar, S. (2012). Analysis of critical success factors of world class manufacturing practices: an application of interpretive structural modeling and interpretive ranking process. *Production Planning & Control*, *23*(10-11), 722-734.

Harting (2016). Reducing the cost of production downtime in the food and beverage industry. Retrieved from: http://www.harting.co.uk/press-news/technical-articles/news/article/reducing-the-cost-of-production-downtime-003652/

Hassan, M., Eldin, A. B., & Ghazali, A. E. (2015). A decision support system for subjective forecasting of new product sale. *International Journal of Computer Applications*, *126*(2), 25-30.

Hudson, H., Shaaban S., & McNamara, T. (2016). Performance of unpaced production lines with unbalanced mean operation times and unreliability patterns. *Journal of Manufacturing Systems*, *41*, 164-172.

Iskander, W. H., & Chou, J. (1990). Unbalanced production line scheduling with partial job specialization. *Naval research Logistics*, *37*(5), 789-805.

Islam, M. M., Khan, A. M., & Islam, M. M. (2016). Application of lean manufacturing to higher productivity in the apparel industry in Bangladesh. *International Journal of Scientific and Engineering Research*, *4*(2), 1-10.

Jharkharia, S., & Shankar, R. (2004). IT enablement of supply chains: modeling the enablers. *International Journal of Production and Performance Management*, *53*(8), 700-712.

Kannan, G., & Haq, N. A. (2006). Analysis of interactions of criteria and sub-criteria for the selection of supplier in the built-in-order supply chain environment. *International Journal of Production Research*, *45*, 1-22.

Kumar, A., Kumar, R., & Rao, K. H. (2012). Enabling efficient supply chain in dairying using GIS: a case of private dairy industry in Andhra Pradesh state. *Indian Journal of Agricultural Economics*, *67*(3), 395-404.

Kumar, A., Staal, S. J., & Singh, D. K. (2011). Smallholder dairy farmers access to modern milk marketing chains in India. *Agricultural Economics Research Review*, *24*, 243-253.

Kumar, R. (2014). Performance measurement in dairy Supply chain management. *Indian Journal of Research*, *3*(3), 100-101.

Lemma, Y., Kitaw, D., & Gatew, G. (2014). Loss in perishable food supply chain: an optimization approach literature review. *International Journal of Scientific and Engineering Research*, *5*(5), 302-311.

Lopez, C. E. (2014). *Unbalanced workload allocation in large assembly lines* (Thesis, Rochester Institute of Technology).

Mangla, S. K., Sharma, Y. K., & Patil, P. P. (2016). Using AHP to rank the critical success factors in food supply chain management. *International Conference on Smart Strategies for Digital World- Industrial Engineering Perspective*, *58*.

Mangla, S., Madaan, J., & Chan, F. T. (2013). Analysis of flexible decision strategies for sustainability-focused green product recovery system. *International Journal of Production Research*, *51*(11), 3428-3442.

Mathiyazhagan, K., Govindan, K., Haq, A. N., & Yong, G. (2013). An ISM approach for the barrier analysis in implementing green supply chain management. *Journal of Cleaner Production*, *47*, 283-297.

Mathiyazhagan, K., & Haq, A. N. (2013). Analysis of the influential pressures for green supply chain management adoption- an Indian perspective using interpretive structural modeling. *The International Journal of Advanced Manufacturing Technology*, *68*(1-4), 817-833.

Mishra, P. K., & Shekhar, B. R. (2011). Impact of risks and uncertainties on supply chain: a dairy industry perspective. *Journal of Management Research*, *3*(2), 1-18.

Mor, R. S., Bhardwaj, A., & Singh, S. (2018a). A structured literature review of the Supply Chain practices in Food Processing Industry. *Proceedings of the 2018 International Conference on Industrial Engineering and Operations Management, Bandung, Indonesia, March 6-8, 2018,* 588-599.

Mor, R. S., Bhardwaj, A., & Singh, S. (2018b). Benchmarking the interactions among Performance Indicators in dairy supply chain: An ISM approach. *Benchmarking: An International Journal,* Accepted for publication.

Mor, R. S., Singh, S., Bhardwaj, A., & Bharti, S. (2017a). Exploring the causes of low-productivity in Dairy industry using AHP. *Jurnal Teknik Industri*, *19*(2), 83-92.

Mor, R. S., Singh, S., & Bhardwaj, A. (2017b). Framework for measuring the Procurement performance in dairy supply chain. *Joint Indo-German Conference on Sustainable Engineering,* Sept. 15-16, 2017 held at BITS Pilani, and Accepted for Springer Book Proceedings.

Mor, R. S., Singh, S., & Bhardwaj, A. (2016). Learning on lean production: A review of opinion and research within environmental constraints. *Operations and Supply Chain Management: An International Journal*, *9*(1), 61-72.

Mor, R. S., Singh, S., Bhardwaj, A., & Singh, L. P. (2015). Technological implications of supply chain practices in agri-food sector- a review. *International Journal of Supply and Operations Management*, *2*(2), 720-747.

Mudgal, R. K., Shankar, R., Talib, P., & Raj, T. (2010). Modeling the barriers of green supply chain practices: an Indian perspective. *International Journal of Logistics Systems and Management*, *7*(1), 81-107.

Nicholas, P., Mandolesi, S., Naspetti, S., & Zanoli, R. (2014). Innovations in low input and organic dairy supply chains- what is acceptable in Europe? *Proceedings of the 4th ISOFAR scientific conference- Organic world congress 2014*, 13-15 Oct., Istanbul, Turkey, 1167-1170.

Okano, M. T., Vendrametto, O., & Santos, O. S. (2014). How to improve dairy production in Brazil through indicators for the economic development of milk chain. *Modern Economy*, *5*, 663-669.

Patel, A. M, Modha, H. M., Patel, D. K., & Patel, H. G. (2014). New product development-opportunities and challenges for traditional Indian dairy products. *National Seminar on Indian Dairy Industry- Opportunities and Challenges*, AAU, Anand, 228-232.

Pesticide Storage and Stock Control Manual, FAO Corporate Document Repository. Retrieved from: http://www.fao.org/docrep/v8966e/V8966e05.htm

Prakash, G., & Pant, R. R. (2013). Performance measurement of a dairy supply chain: a balance scorecard perspective. *Proceedings of the 2013 IEEE IEEM*, 196-200.

Prasad, R., & Satsangi, R. (2013). A case study of Amul cooperative in India in relation to organizational design and operational efficiency. *International Journal of Scientific and Engineering Research*, *4*(1), 1-9.

Rahul, & Kaler, J. S. (2013). Eradication of productivity related problems through lean principles in integrated manufacturing environment. *International Journal of Lean Thinking*, *4*(1), 71-88.

Ravi, V., & Shankar, R. (2005). Analysis of interactions among the barriers of reverse logistics. *Technological Forecasting and Social Change*, *72*, 1011-1029.

Sadowski, R. P., & Medeiros, D. J. (1979). The effect of variability on the unbalanced production line. *International Journal of Production Research*, *17*(6), 527-540.

Shaaban, S., McNamara, T., & Hudson, H. (2013). The effects of unbalancing operation time variability on the performance of unreliable lines. *Journal of Manufacturing Technology Management*, *24*(3), 428-447.

Shagluf, A., Longstaff, A. P., & Fletcher, S. (2014). Maintenance strategies to reduce downtime due to machine positional errors. *COIMBRA*, 111-118. doi: http://dx.doi.org/10.14195/978-972-8954-42-0_25.

Singh, M. D., Singh, S., Chokshi, A., Chavan, H., & Dabhi, D. (2015). Process Flow Improvement through 5S, Kaizen and Visualization. *International Journal of Innovative Research in Science, Engineering and Technology*, *4*(3), 1103-1112.

Singh, R., Gohil, A. M., Shah, D. B., & Desai, S. (2013). Total Productive Maintenance (TPM) Implementation in a Machine Shop: A Case Study. *Procedia Engineering*, *51*, 592-599.

Sugiarto, V. C., Sarno, R., & Sunaryono, D. (2016). Sales forecasting using holt-winters in enterprise resource planning at sales and distribution module. *IEEE International Conference on ICTS, Indonesia,* 8-13.

Vijayakumar, G., & Robinson, Y. (2016). Impacts of lean tools and techniques for improving manufacturing performance in garment manufacturing scenario: a case study. *International Journal of Advances in Engineering & Technology*, *7*(2), 251-260.

Warfield, J. W. (1974). Developing inter connected matrices in structural modeling. *IEEE Transactions on Systems, Man, and Cybernetics*, *4*(1), 51-81.

Yam, K. L. (2010). *The Wiley Encyclopedia of Packaging Technology*. John Wiley and Sons, 2010.

Zhou, Q., Han, R., & Li, T. (2015). A two-step dynamic inventory forecasting model for large manufacturing. *14th International Conference on Machine Learning and Applications, Miami*, 749-753.

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