Raw Milk Procurement in Dairy Supply Chain: Analysis of Influencing Factors

Susmita Bandyopadhyay[1*], Indraneel Mandal[2]

[1]Department of Business Administration, University of Burdwan, West Bengal-713104, India
[2]Institute of Technology and Science, Mohan Nagar, Ghaziabad, India
[*1] bandyopadhyaysusmita2010@gmail.com

Abstract. The existing literature does not show enough research studies on dairy milk supply chain. The research work investigates the nature of factors that affect raw milk procurement in a dairy supply chain; the factors have been gathered from the existing literature. The natures of a total ten factors have been analysed based on the opinions of some experts in the relevant practicing field. Analysis of the data collected has been carried out using the Interpretive Structural Model and further investigated by Cross-Impact Matrix Multiplication Applied to Classification (MICMAC). This research categorizes the factors into four classes: autonomous factors, dependent factors, independent factors, and linkage factors. The primary reason behind the classification is to make an identification of the most critical factors determining the maximum impact on the dairy supply chain with reference to raw milk procurement to accord special emphasis on shelf life, safety, and freshness of milk.

Keywords: Interpretive Structural Model, MICMAC, Factors, Milk Procurement, Dairy Supply Chain.

1   Introduction

Any aspect of the dairy supply chain investigation is quite a challenge to any researcher as very little work has been done on any aspect. However, milk is a very emphasized food item in all societies of the world; thus, the dairy supply chain is very important to any society of the world. Research on the review of the literature available says that in India, 55% and 45% of milk produce are consumed by different international companies and local cooperatives, respectively. There are many challenges that the dairy supply chain faces. Among those, the most prime ones are related to wastage minimization, price optimization, storage management, processing, and marketing of milk and many more such perishable items. To this respect, the area of investigating into the factors affecting raw milk procurement is likely to draw the attention of the researchers, and the motivation toward this research is thus prominent. This paper analyses the nature of a total of ten factors (collected from existing literature) through Interpretive Structural Model and further explores through MICMAC analysis, based on the opinions of a group of practitioners in the relevant

practicing field. The rest of the paper is organized as follows – Section 2 reviews the existing relevant literature; Section 3 presents the procedure of ISM and MICMAC analysis which has been applied in this paper; Section 4 applies these techniques on the described problem and thus, the results and discussion are also included in this section; Section 5 concludes this paper.

2   Literature Review

There are a very limited number of existing literature research articles focused on different aspects of the dairy supply chain. For instance, Banerjee et al. [1] probed the challenges of food safety issues in the dairy supply chain. In this regard, Malliaroudaki et al. [2] looked for alternative energy options to the energy supply chain as global climate change might render handling dairy products very difficult. Kazancoglu et al. [3] proposed a framework to overcome the barriers against "circularity" of dairy supply chains. Else et al. [4] emphasized sustainability in the dairy supply chain. Wang et al. [5] proposed a cost-effective model of food safety monitoring and analysed the effectiveness of the proposed model through the practical case study. Montgomery et al. [6] discussed the 2015-2019 dairy supply chain's safety and authenticity issues. Liu et al. [7] created an "automated food-safety warning system" based on Bayesian networking and proved that the developed model is useful for food safety monitoring. Ding et al. [8] revealed the factors that influence the gaining of a competitive advantage for Chinese dairy firms. Guarnaschelli et al. [9] addressed the problem of production and distribution planning for the dairy supply chain using a two-stage Stochastic Mixed-Integer Programming approach. The authors have also proposed the methodology to solve the proposed mathematical model. Pant et al. [10] proposed the framework for handling the traceability and transparency problems for the dairy supply chain. Other important research studies along with the issues focused on are enlisted in Table 1. From this literature review, it can easily be noticed that the focus area of this current paper has been addressed very little in the available literature. This paper fills up this gap of research by analysing and classifying factors that influence the raw milk procurement in a dairy supply chain.

Table 1. Some Significant Contributions in Dairy Supply Chain.

Author and Year	Issue Addressed
Mandolesi et al. [11]	Proposed a Q-Methodical study for studying the innovativeness for low-input organic dairy farms.
Nirmala et al. [12]	Investigated risk mitigation ways for dairy supply chain management.
Tan and Ngan [13]	Proposed a model of traceability for dairy supply chain.
Yawar and Kauppi [14]	Investigated into the supplier development process for dairy supply chain in India.
Kirilova et al. [15]	Optimized the design of green product portfolio in terms of curd production.

However, some other research studies on both dairy milk supply chain and the methods as discussed above include the research studies of Glover et al. [16], Kumar

and Singh [17], Nicholas et al. [18], Sel et al. [19], Subburaj et al. [20], Vaklieva-Bancheva et al. [21].

3   ISM Method and MICMAC Analysis

In this paper, the Interpretive Structural Model has been applied and further elaborated by MICMAC analysis for analysing and classifying the factors that influence raw milk procurement. Both these methods have been explained briefly in the following subsections.

3.1   Interpretive Structural Model (ISM)

The steps of ISM are shown in Figure 1. ISM, originally developed by J. Warfield in 1973 [16] is basically a Multicriteria Decision Analysis (MCDA) technique like many other techniques with special characteristics like, depicting the relationships among the variables clearly and through graphics, expressing the strength of relationships as well, although the method is complex by nature. At first, after identifying the variables in a problem, experts' opinions can be taken to characterize the variables in terms of relationships into the following four types - F: Factor V_i influences factor V_j; R: Factor V_j influences factor V_i; FR: Both factors V_i and V_j influence each other; X: Factors V_i and V_j are independent of each other. These relations among each pair of variables form the SSIM (Structural Self-Interaction Matrix) matrix. This matrix is now converted to Initial Reachability Matrix (IRM) by the following rule – (a) if the relation is 'X', the both the cells, C_{ij} and C_{ji} are 0 (zero); if the relation is 'F' then C_{ij} = 1 and C_{ji} = 0; if the relation is 'R' then C_{ij} = 0 and C_{ji} = 1; if the relation is 'FR' then C_{ij} = C_{ji} = 1. Next identify the transitive relationships among the variables. If "X implies Y and Y implies Z then X implies Z$" – the derived relation between X and Z is called transitive relation. Represent all these transitive relation by "$1\#$" instead of '1' or '0' and in this way form the Final Reachability Matrix (FRM). Next, find reachability set for each variable. This is the set of variables for each variable 'V', for which the row elements for 'V' are '1'. Find antecedent set for each variable 'V', for which the column elements for 'V' are '1'. The intersecting or common elements between reachability set and antecedent set are known as intersection set. These reachability set, antecedent set and intersection set for each variable are found for both the IRM and FRM matrices. Next, these variables are classified into different hierarchical levels based on these 3 sets and FRM. Each level contains variables that are common in both reachability set and intersection set. After each level is complete, the variables in the created level are all removed from the reachability set, antecedent set and intersection set and then the resultant reachability set and intersection set are checked for common variables to form the variables for the next level. The Conical Matrix (CM) is then formed from FRM. Here, the row and column of CM represent are variable placed serially starting from level 1 variables to the last level variables.

Now, Initial Digraph is drawn, showing the relationships among each pair of variables in FRM matrix and transitively related variables' links are differently marked (with different colour or dotted lines). Relation '*FR*' is represented by double oppositely directional arrows. Final Digraph is then drawn by removing the transitive relational arrows in the Initial Digraph. This Final Digraph is constructed with geometric lines clearly to represent the required Interpretive Structural Model (ISM) that clearly and visually shows the relationship between variables. Thus, this ISM figure 1 is the resultant product of the ISM method.
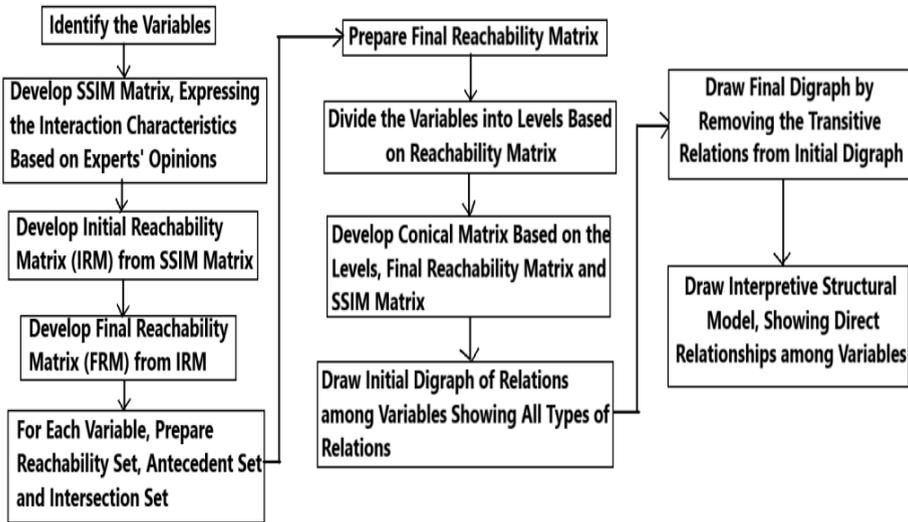
Fig. 1. Method of ISM

3.2   Cross-Impact Matrix Multiplication Applied to Classification (MICMAC)

ISM shows the direct relations among the variables of a problem and also helps to derive other relations as well. But in order to get the extent or degree to which the variables influence each other, a simple method known MICMAC is applied. The result of ISM method is the input of MICMAC analysis. In MICMAC, at first, count the number of *1's* in each row (called the Driving Power) and the number of *1's* in each column (called the Dependence Power). Then, classify the variables into the following categories and show these classifications by a graph with Driving power on vertical axis and Dependence power on horizontal axis. This simple analysis is called MICMAC analysis. The following section shows the applications of ISM and MICMAC on dairy example:

Autonomous variables – Variables with low driving power and low dependence power;

Dependent Variables – Variables with low driving power and high   dependence power;

Independent Variables – Variables with high driving power and low dependence power

Linkage Variables – Variables with high driving power and high dependence power

4   Results and Discussion

The review of the existing literature has resulted in a total of 10 different factors which affect the procurement of raw milk in dairy supply chain. These factors are – Relation between the buyer (milk supplier) and the seller (dairy firm) (R); Seasonal Variation (S); Food effect (F); Health of the animal (H); Perishable nature of the product (milk) (P); Market demand (M); Cost of transportation (C); Storage for milk (ST); Variations of price in the procurement of milk (V); Awareness of the dairy firm (A). A total of 4 practitioners have been gathered together to find the influence relations among each pair of these variables resulting in a matrix (SSIM matrix) as shown in Table 2. The 4 practitioners all belong to dairy industry- two of them are in middle-level management in a dairy firm, the two other practitioners is a supplier of dairy products.

Table 2. SSIM Matrix.

	R	S	F	H	P	M	C	ST	V	A
A	R	X	R	R	F	X	R	R	R	
V	F	R	F R	F	F	F R	R	F		
ST	F R	F	X	X	F	F	R			
C	R	F	X	X	F	F				
M	X	F	X	F	X					
P	X	X	R	X						
H	R	F	F R	R						
F	X	F R								
S	R									
R										

Then, following the method as depicted in section 3.1, Initial Reachability Matrix (IRM) is obtained as shown in Table 3. By representing the transitive relations among variables by '*1#*', FRM is obtained as shown in Table 4. Next, following the method as depicted in section 3.1, reachability set, antecedent set and intersection set have been identified for each variable from IRM as shown in Table 5.

Table 3. Initial Reachability Matrix (IRM).

	A	V	ST	C	M	P	H	F	S	R
A	1	0	0	0	0	1	0	0	0	0
V	1	1	1	0	1	1	1	1	0	1
ST	1	0	1	0	1	1	0	0	1	1
C	1	1	1	1	1	1	0	0	1	0
M	0	1	0	0	1	0	1	0	1	0
P	0	0	0	0	0	1	0	0	0	0
H	1	0	0	0	0	0	1	1	1	0
F	1	1	0	0	0	1	1	1	1	0
S	0	1	0	0	0	0	1	1	1	0
R	1	0	1	1	0	0	1	0	1	1

Table 4. Final Reachability Matrix (FRM).

	A	V	ST	C	M	P	H	F	S	R
A	1	0	0	0	0	1	0	0	0	0
V	1	1	1	1#	1	1	1	1	1#	1
ST	1	1#	1	1#	1	1	1#	1#	1	1
C	1	1	1	1	1	1	1#	1#	1	1#
M	1#	1	1#	0	1	1#	1	1#	1	1#
P	0	0	0	0	0	1	0	0	0	0
H	1	1#	0	0	0	1#	1	1	1	0
F	1	1	1#	0	1#	1	1	1	1	1#
S	1#	1	1#	0	1#	1#	1	1	1	1#
R	1	1#	1	1	1#	1#	1	1#	1	1

Table 5. Reachability Set, Antecedent Set, and Intersection Set from IRM.

Variables	Reachability Set	Antecedent Set	Intersection Set
A	A,P	A,V,ST,C,H,F,R	A
V	,V,ST,M,P,H,F,R	V,C,M,F,S	V,M,F
ST	A,ST,M,P,S,R	V,ST,C,R	ST,R
C	A,V,ST,C,M,P,S	C,R	C
M	V,M,H,S	V,ST,C,M	V,M
P	P	A,V,ST,C,P,F	P
H	A,H,F,S	V,M,H,F,S,R	H,F,S
F	A,V,P,H,F,S	V,H,F,S	V,H,F,S
S	V,H,F,S	ST,C,M,H,F,S,R	H,F,S
R	A,ST,C,H,S,R	V,ST,R	ST,R

For example, in Table 4 (FRM), in the row of variable '*A*' (first row), the number of '*1*'s is 2 under columns *A* and *P*. Thus, the elements in reachability set for variable '*A*' are *A* and *P* as shown in Table 5. In Table 4 (FRM), in the column of variable '*A*' (first column), the number of '*1*'s is 6 against rows of *A, V, ST, C, H, F, R*. Thus, the elements in antecedent set for variable '*A*' are *A, V, ST, C, H, F, R* as shown in Table 5. There is only one common element '*A*' between these two sets for variable '*A*' and thus, the intersection set for variable '*A*' contains element '*A*'. Similarly, the elements of the three sets are identified for other variables following the same procedure. The same procedure is following to find the reachability set, antecedent set and the intersection set from FRM matrix and are shown in Figure 2.

Variables	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET
A	A, P	A, V, ST, C, M, H, F, S, R	A
V	A, V, ST, C, M, P, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, C, M, H, F, S, R
ST	A, V, ST, C, M, P, H, F, S, R	V, ST, C, M, F, S, R	V, ST, C, M, F, S, R
C	A, V, ST, C, M, P, H, F, S, R	V, ST, C, R	V, ST, C, R
M	A, V, ST, M, P, H, F, S, R	V, ST, C, M, F, S, R	V, ST, M, F, S, R
P	P	A, V, ST, C, M, P, H, F, S, R	P
H	A, V, P, H, F, S	V, ST, C, M, H, F, S, R	V, H, F, S
F	A, V, ST, M, P, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, M, H, F, S, R
S	A, V, ST, M, P, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, M, H, F, S, R
R	A, V, ST, C, M, P, H, F, S, R	V, ST, C, M, F, S, R	V, ST, C, M, F, S, R

Fig 2. Reachability Set, Antecedent Set, and Intersection Set from FRM.

Next, these variables are arranged in hierarchical levels based on the matrix as shown in Table 6, by following the method as depicted in section 3.1. For example, the elements are common (variable, P) only for variable *P* and thus, level 1 contains only variable *P*. Variable *P* is then removed from all the three sets in Table 6 and the row of P is also removed, resulting in figure 3.

Variables	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET
A	A	A, V, ST, C, M, H, F, S, R	A
V	A, V, ST, C, M, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, C, M, H, F, S, R
ST	A, V, ST, C, M, H, F, S, R	V, ST, C, M, F, S, R	V, ST, C, M, F, S, R
C	A, V, ST, C, M, H, F, S, R	V, ST, C, R	V, ST, C, R
M	A, V, ST, M, H, F, S, R	V, ST, C, M, F, S, R	V, ST, M, F, S, R
H	A, V, H, F, S	V, ST, C, M, H, F, S, R	V, H, F, S
F	A, V, ST, M, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, M, H, F, S, R
S	A, V, ST, M, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, M, H, F, S, R
R	A, V, ST, C, M, H, F, S, R	V, ST, C, M, F, S, R	V, ST, C, M, F, S, R

Fig 3. The Sets after Removing Variable *P.*

The elements in Table 7 are common (variable, A) only for variable A and thus, level 2 contains only variable A. Variable A is then removed from all the three sets in Table 7 and the row of A is also removed, resulting in figure 4.

Variables	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET
V	V, ST, C, M, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, C, M, H, F, S, R
ST	V, ST, C, M, H, F, S, R	V, ST, C, M, F, S, R	V, ST, C, M, F, S, R
C	V, ST, C, M, H, F, S, R	V, ST, C, R	V, ST, C, R
M	V, ST, M, H, F, S, R	V, ST, C, M, F, S, R	V, ST, M, F, S, R
H	V, H, F, S	V, ST, C, M, H, F, S, R	V, H, F, S
F	V, ST, M, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, M, H, F, S, R
S	V, ST, M, H, F, S, R	V, ST, C, M, H, F, S, R	V, ST, M, H, F, S, R
R	V, ST, C, M, H, F, S, R	V, ST, C, M, F, S, R	V, ST, C, M, F, S, R

Fig 4. The Sets after Removing Variable A.

The elements in Table 8 are common only for variables V, H, F, S and thus, level 3 contains variables V, H, F, S. These variables are then removed from all the three sets in Table 8 and the respective rows are also removed, resulting in figure 5.

Variables	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET
ST	ST, C, M, S	ST, C, M, S	ST, C, M, S
C	ST, C, M, S	ST, C	ST, C
M	ST, M, S	ST, C, M, S	ST, M, S
R	ST, C, M, R	ST, C, M, R	ST, C, M, R

Fig 5. The Sets after Removing Variables V, H, F, S.

The elements in Table 9 are common only for variables ST, M, R and thus, level 4 contains variables ST, M, R. These variables are then removed from all the three sets in Table 9 and the respective rows are also removed, resulting in the remaining row C. Thus, level 5 contains the variable C. The levels are summarized in Table 6.

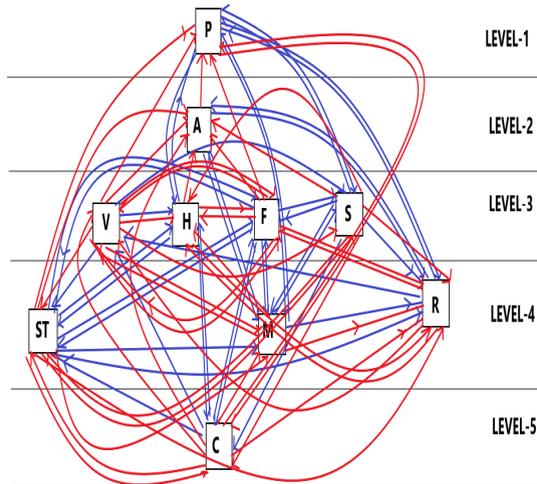**Table 6.** Variables Arranged in Hierarchical Levels.

LEVELS	VARIABLES
1	P
2	A
3	V, H, F, S
4	ST, M, R
5	C

Next, following the method as depicted in section 3.1, Conical Matrix is formed as shown in Table 7. Observe that the variables are arranged as row and column captions in the order of levels. Thus, level 1 variable P represents the first row and first column following by level 2 variable A which is following by level 3 variables V, H, F, S and so on. These relations including transitive relations are summarized in figure 6. The transitive relational connections are then removed from figure 7 to show

only the direct relations and the Final Digraph is formed. This diagram is then re-drawn clearly with geometric straight links as shown in Figure 7.

Table 7. Conical Matrix.

	P	A	V	H	F	S	ST	M	R	C
P	1	0	0	0	0	0	0	0	0	0
A	1	1	0	0	0	0	0	0	0	0
V	1	1	1	1	1	1#	1	1	1	1#
H	1#	1	1#	1	1	1	0	0	0	0
F	1	1	1	1	1	1	1#	1#	1#	0
R	1#	1	1#	1	1#	1	1	1#	1	1
S T	1	1	1#	1#	1#	1	1	1	1	1#
M	1#	1#	1	1	1#	1	1#	1	1#	0
S	1#	1#	1	1	1	1	1#	1#	1#	0
C	1	1	1	1#	1#	1	1	1	1#	1

Fig. 6. Initial Digraph

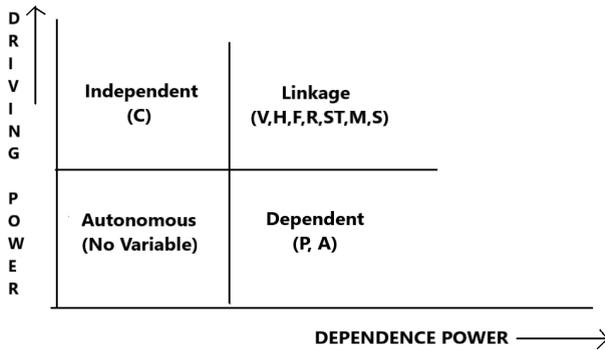**Fig. 7**. Interpretive Structural Model

Fig. 8 . Dependency Model

Figure 7 is the result of ISM method as applied in this paper. Now, MICMAC analysis is performed to find the degree of these relationships among the variables. Following the method as depicted in section 3.2, driving power and dependence power are calculated for each variable as shown in figure 9. For example, the total number of 1's for rows of variables *P* and *A* are 1 and 2 respectively. The total number of 1's for columns of variables *P* and *A* are 10 and 9 respectively. Thus, the driving power for variables *P* and *A* are 1 and 2 and the dependence power for these variables are 10 and 9 respectively. Figure 8 shows clear division of low and high values of driving and dependence power. Thus, the following classifications can be done. These

classifications are shown in figure 8 as MICMAC graph which is the result of MICMAC analysis.

Autonomous Variables – low driving power, low dependence power: No such variable is seen
Dependent Variables – low driving power, high dependence power: P, A
Independent Variables – high driving power, low dependence power: C
Linkage Variables – high driving power, high dependence power: V, H, F, R, ST, M, S

Fig. 9. Driving Power and Dependence Power.

	P	A	V	H	F	S	ST	M	R	C	Driving Power	
P	1	0	0	0	0	0	0	0	0	0	1	LOW
A	1	1	0	0	0	0	0	0	0	0	2	
V	1	1	1	1	1	1#	1	1	1	1#	10	HIGH
H	1#	1	1#	1	1	1	0	0	0	0	6	
F	1	1	1	1	1	1	1#	1#	1#	0	9	
R	1#	1	1#	1	1#	1	1	1#	1	1	10	
ST	1	1	1#	1#	1#	1	1	1	1	1#	10	
M	1#	1#	1	1	1#	1	1#	1	1#	0	9	
S	1#	1#	1	1	1	1	1#	1#	1#	0	9	
C	1	1	1	1#	1#	1	1	1	1#	1	10	
Dependence Power	10	9	8	8	8	8	7	7	7	4		
	HIGH									LOW		

5   Conclusion

This paper has applied Interpretive Structural Model (ISM) and further explored by MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) analysis on a study on raw milk procurement in dairy supply chain. The purpose is to analyse and classify the variables as identified from extensive literature review. A total of 10 such variables have been identified. The relationships have been established among these variables with help of ISM method and the degrees of relationships have been determined by MICMAC analysis which has classified the variables into four categories, autonomous variables, dependent variables, independent variables and linkage variables. The initial data on the primary relationships between each pair of variables is obtained as a result of collective decisions of four practitioners in the respective field of dairy supply chain. ISM method (a Multicriteria Decision Analysis technique) has been chosen because ISM is applicable for those problem where sufficient numerical data are not available and complex decisions will have to be taken based on the qualitative data gathered.

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