

# Study on the Factors Affecting Logistics & Supply Chain of Food Products Using Interpretive Structural Modelling (ISM)

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## ABSTRACT

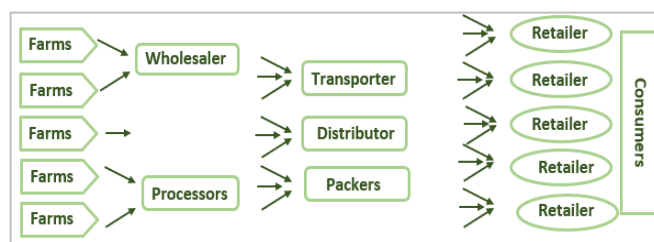
A Supply Chain is the most crucial element in any business these days. For products with less shelf life i.e. those which are likely to get spoiled fast like fresh vegetables, fruits, dairy products, poultry, etc the supply chain and in turn its logistics turns to be more important for the business. This paper targets to explore and understand the components that majorly impact the performance of the supply chain and also the relationship between these factors/variables. Interactions with professionals across Hospitality and FMCG industries in form of telephonic interviews and questionnaires were used to identify the factors/variables and their dependencies. The data obtained from the survey was analysed in Interpretive Structural Modelling (ISM) and Matrice des Impacts Croises Multiplication Applique a un Classement (MICMAC) to formulate a well-defined model to interpret the important decisions. The findings of this paper will provide a comprehensive picture about the factors majorly affecting the Supply chain and logistics of perishable items that aid for effective planning and decision making.

## Keywords

Perishables, Supply Chain, Logistics, Interpretive Structural Modelling (ISM), MICMAC  
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## Introduction

The first and foremost priority of any business is their customer satisfaction in the current scenario. Keeping this in mind most of the companies are undergoing strategy, operational and technological revolutions to satisfy the demand and to be the leader in the market (Scavarda, A., 2014). Businesses need to be highly responsive to the demand in the current scenario. This can be made possible only by the efficient management of supply chain. Supply Chain Management is a very wide topic and was studied by multiple researchers from different perspectives/angles (Lemma, 2014). This paper focuses on the logistics and supply chain associated with perishable products. Things or items that have a very short shelf life and are likely to get spoiled or decayed quickly can be called as perishables. Products which when kept in stock decay or will be destroyed shows the perishable characteristics (Dolgui, A., 2018). This includes different items like vegetables, fruits, poultry, dairy products and these are majorly handled by Retail Sector, Hospitality, FMCGs etc. A simple Supply chain of these perishable can be depicted as below:



**Figure 1: A Schematic Diagram of Perishable Supply Chain**

The upstream supply chain for procuring perishables generally involves various stakeholders such as farmers, retailers, aggregators, storage providers, distributors, etc. Also, considering the short product life of these items the supply chain turnaround is very short ranging from hours to few days. Today's consumers are well informed from the existing and growing market campaigns about the need and importance of healthy/quality products for consumption and are focused on their health and wellbeing (Cognizant 20-20 Insights). Therefore, when it comes to perishable items, they need fresher and nutritious products. These intrinsic attributes of food items-mainly the perishability and need to maintain high consumer confidence makes the food supply chain management challenging (Aruna, 2010). Freshness is a key parameter in handling perishable items as equal to their quality. Facilitating the freshest product to the customer is a challenge in the current retail

scenario and for achieving this the supply chain of the business need to be highly responsive and efficient. This makes it very relevant to understand the different variables or components influencing the perishable supply chain and can be worked upon by companies to develop a well efficient supply chain.

This paper explores different factors which will affect the supply chain of perishables like its cost, infrastructure requirement, transport efficiency, etc. These factors are studied and the dependency among these are identified with the help of experienced professional in this sector to develop a model. ISM and MICMAC is adopted in this paper to formulate a well-defined model. In this model different factors and its hierarchical levels are defined which help in understanding and generating insights on which all factors need to be paid attention in developing a perishable supply chain. Perishable supply chain, logistics and inventory management of perishable item were studied by multiple researchers over the time. Majority of these researches focused on perishability part of food items, how to manage this concern and how this is affecting the supply chain (Dagne, 2020). But in the current scenario where developing an efficient Supply chain is vital for the business, more and more factors need to be identified and their relation to be studied and established in order to draw better decisions and insights for the planning and execution.

The layout of this research is framed in the given manner: 2<sup>nd</sup> Section explains multiple literature pieces referred for detailed study about the industry and the process. The methodology adopted in doing this research is recorded in the 3<sup>rd</sup> Section. 4<sup>th</sup> Section describes the ISM and MICMAC analysis used for data analysis and developing the model. 5<sup>th</sup> Section gives the result of the research, concludes the paper and explains the future scope that can be done in this area of research. This paper aims at giving an overview of the variables considered in developing an efficient perishable supply chain which helps managers in planning and decision making.

### Literature Review

Multiple factors affect the efficiency of logistics and supply chain of perishables. According to Pal, A. (2019), logistics networks plays an important role in the perishable supplies. Logistics networks

or the transport facilities need to be highly agile and efficient in order to develop a high velocity perishable supply chain and automation can play a key role Pal, A. (2019). Infusion of Information technology, Internet of Perishable Logistics (IoPL) etc. are very impactful in making the logistics/transport networks more simplified and better analysable. Ferreira, G.O., (2018) considers the perishability as an important factor in supplies management. They mention that the perishability or shelf life if not taken care for supplies can harm the customers and also will generate disposal costs. Also, this will impact the customer satisfaction to a greater extent. Perishability can include the shelf life, freshness, temperature, packaging requirements, etc. Castro, (2017), states the importance of perishability in supply chain. In food supply chain they state that from the time the product leaves the grower and reaches the consumer the quality/freshness changes continuously and this need to be taken care. According to Grunow (2013), traceability for perishables like vegetables, fruits, dairy products is becoming a vital factor in its supply chain. In the paper they mentioned that proper traceability of perishable supply chain provides real-time visibility for tracking, reduced opportunity for spoilage, identification of contaminated items, etc. Lin (2016) in their research mentions that real-time traceability makes the supply chain more efficient and transparent.

Rijkema (2014) refers to cost as a key performance indicator in the perishable supply chain. He mentions that cost reflects the performance of processes involved in the supply chain. It considers different costs like transportation cost, storage cost, shortage costs, etc. In the study he analyses how the sourcing or supply chain can be made effective by considering costs. Scavarda (2014), states that the service level and order fulfilment time are two important parameters in supply chain of perishables. They mention that a decision on supply chain strategy is a choice between the efficiency and responsiveness. The SC strategic decisions will be affected by the market, quality and customer demand. They mention that speed, sustainability and ability to match the customer/ market demand are main characteristics of perishable food market. Yang (2017), in the paper studies both the economic and sustainable aspect of Perishable

supply chain. The uncertain demand and mass spoilage result in frequent shortage of items. In the study Yang (2017) mentions that beside the economic effect, because of the perishable property the perishable supply chain is different from the normal supply chains and is crucial for the sustainability of the system. They suggest that a better sustainable supply chain requires involvement of all stake holders and also effective coordination.

According to Salah (2009), multiple factors affect the development of an efficient supply chain for perishables. The study shows that infrastructure availability, storage conditions, warehouse capacities, etc plays key role in modelling an efficient supply chain. Based on the study of Javier (2013), the high perishability of food items leads to poor quality and profit, which leads to the need of better storage facilities and transport solutions. Modelling techniques are very important in designing research model and in decision making. One such important and widely used technique is ISM. In order to figure out the important factors in corporate governance Ukyet al. (2018) used ISM Tool. In their paper they mention that ISM holds multiple advantages over AHP and TOPSIS as it considers the hierarchical structure for the considered variables. Ahmad (2019) in his paper to identify significant factors affecting Seismic Soil Liquefaction used ISM and MICMAC tools to draw conclusion. ISM model is used in the paper to establish relationship between the factors identified and to benchmark the position of variables in hierarchy from higher to lower level. And MICMAC is adopted to understand the power of relationship between variables according to its power of driving and dependence

To conclude, different components impacting the supply chain of perishable goods include cost, sustainability, infrastructure, shelf life, order fulfilment time, market demand, IT/automation, service level, storage conditions, efficient transport facilities, supply chain traceability and regulatory guidelines. Perishability (shelf life) is considered as the most important component in framing the supply chain model for perishables. This study aims at understanding the relationship between all the identified factors and checks whether shelf life/perishability is the driving

factor in perishable supply chain. This model gives a holistic view on how these variables are interrelated and how an efficient supply chain model can be formulated.

### Methodology

On identifying the factors, a questionnaire was created as the next step in order to collect the opinions from experienced professionals in this domain. A total of 12 variables were selected and the questionnaire was formed in the form of a 12 X 12 matrix. In this study 14 professionals were identified from different sectors like hospitality-hotel business, aggregators, logistics experts, etc This questionnaire was circulated via email to collect information from identified professionals and responses were collected in the form of telephonic interviews. The survey was conducted over 1-week timeline and the experts consulted were having relevant experience in working with Supply Chain, Logistics, perishable inventory management. Interpretive Structural Modelling (ISM) was performed on the data collected through survey. ISM is an important tool in establishing relationships and understanding interactions between variables through a pair-wise comparison method. ISM consists of 8 steps as briefed below:

STEP 1: Identifying and listing out the factors/variables required for analysis. The summary of same is given in Table 1.

STEP II: Prepare questionnaire and develop relationship between these variables using survey.

STEP III: Develop Structural Self-Interaction Matrix (SSIM) which will give the pairwise relationship among the considered variables.

STEP IV: To understand and establish transitivity link among variables formulate SSIM Initial Reachability Matrix.

STEP V: SSIM Initial Reachability Matrix partition into multiple levels.

STEP VI: Removal of transitivity links and creation of Digraph.

STEP VII: Formulation of ISM Model.

STEP VIII: Check for any modification needed in the model.

Table 1: Factors identified and notations

SN	VARIABLES	NOTATION
1	Costs	E1
2	Sustainability	E2
3	Infrastructure	E3
4	Regulatory guidelines	E4
5	Order fulfilment time	E5
6	Shelf life of product	E6
7	Market Demand	E7
8	Supply chain traceability	E8
9	IT/Automation	E9
10	Service level requirements	E10
11	Storage conditions required to ensure Quality	E11
12	Efficient Transport facilities	E12

The responses collected from all 14 samples are collated to prepare a Structural self-Interaction Matrix (SSIM). This matrix is formed by considering the mode of majority votes from the responses received. Considering all the responses being in the VAXO format, proceeding with Mean was not an option. For each and every factor all the 14 responses were analysed and then the majority vote was taken to make the SSIM.

**Data Analysis**

Post to the formulation of questionnaire and survey, SSIM was formed. The matrix thus prepared is recorded as Table 2.

Table 2: Structural self-Interaction Matrix (SSIM)

	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2	E1
E1	A	A	A	A	A	O	A	A	O	A	A	X
E2	O	O	O	O	O	V	O	O	O	X	X	
E3	O	X	A	X	O	O	A	X	A	X		
E4	V	V	O	V	V	O	V	O	X			
E5	A	O	X	A	O	X	A	X				
E6	O	A	O	O	O	O	X					
E7	V	A	V	V	A	X						
E8	A	O	V	A	X							
E9	V	O	V	X								
E10	X	X	X									
E11	O	X										
E12	X											

The VAXO nomenclature followed in the formulation of SSIM matrix stands for:

[ 'i' considered as Row and 'j' considered as Column]

- V: 'i' influence 'j'; 'j' doesn't influence 'i'
- A: 'j' influence 'i'; 'i' doesn't influence 'j'
- X: 'i', 'j' influences each other.
- O: 'i', 'j' is not influencing each other.

In the next stage this matrix is converted into Initial Reachability Matrix. It is a binary matrix with the VAXO terminologies converted into 0 and 1.

Table 3: Rules for Transformation of SSIM to Reachability Matrix

Entry in SSIM	Entry in Initial Reachability Matrix	
	(i, j)	(j, i)
V	1	0
A	0	1
X	1	1
O	0	0

The transformation will be as below:

- In SSIM, if V is the entry in (i, j); cell (i, j) turns into 1 and cell (j, i) turns into 0 in the Reachability Matrix.
- In SSIM, if A is the entry in (i, j); cell (i, j) turns into 0 and the (j, i) turns into 1 in the Reachability Matrix.
- In SSIM, if X is the entry in (i,j); cell (i, j) and (j, i) turns into 1 in the Reachability matrix
- In SSIM, if O is the entry in (i,j); both (i,j) and (j,i) cells turns into 0 in the Reachability matrix (Amrina, E, 2020)

Table 4: Initial Reachability Matrix

	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2	E1
E1	0	0	0	0	0	0	0	0	0	0	0	1
E2	0	0	0	0	0	1	0	0	0	1	1	1
E3	0	1	0	1	0	0	0	1	0	1	1	1
E4	1	1	0	1	1	0	1	0	1	1	0	0
E5	0	0	1	0	0	1	0	1	0	1	0	1
E6	0	0	0	0	0	0	1	1	0	1	0	1
E7	1	0	1	1	0	1	0	1	0	0	0	0
E8	0	0	1	0	1	1	0	0	0	0	0	1
E9	1	0	1	1	1	0	0	1	0	1	0	1
E10	1	1	1	0	0	0	0	1	0	1	0	1
E11	0	1	1	0	0	1	1	0	0	1	0	1
E12	1	0	1	0	1	0	0	1	0	0	0	1

As the next step the transitivity links are established. As per the rule of Transitivity if the variable 'A' impacts 'B' and 'B' impacts 'C' then 'A' will impact 'C'. Final Reachability Matrix is formulated after establishing these transitivity links (Kumar, S.,2016). This is done with the help of ISM Package in Minitab. The Final Reachability Matrix thus obtained is illustrated in below Table 5.

Table 5: Final Reachability Matrix

	E 1	E 2	E 3	E 4	E 5	E 6	E 7	E 8	E 9	E 10	E 11	E 12	Driving Power
E1	1	0	0	0	0	0	0	0	0	0	0	0	1
E2	1	1	1	0	1	1	1	1	1	1	1	1	11
E3	1	1	1	0	1	1	1	1	1	1	1	1	11
E4	1	1	1	1	1	1	1	1	1	1	1	1	12
E5	1	1	1	0	1	1	1	1	1	1	1	1	11
E6	1	1	1	0	1	1	1	1	1	1	1	1	11
E7	1	1	1	0	1	1	1	1	1	1	1	1	11
E8	1	1	1	0	1	1	1	1	1	1	1	1	11
E9	1	1	1	0	1	1	1	1	1	1	1	1	11
E10	1	1	1	0	1	1	1	1	1	1	1	1	11
E11	1	1	1	0	1	1	1	1	1	1	1	1	11
E12	1	1	1	0	1	1	1	1	1	1	1	1	11
Depen dence	1	1	1	1	1	1	1	1	1	1	1	1	
	2	1	1	1	1	1	1	1	1	1	1	1	

This matrix formulated is then used to find the dependence and driving power of components. The sum of row entries will give driving power and sum of columns will give the dependence power of these variables. This data is used to partition the variables into different levels.

Table 6: Level Matrix

NOTATION	VARIABLES	DRIVING POWER	LEVEL
E1	Costs	1	1
E2	Sustainability	11	2
E3	Infrastructure		
E5	Order fulfilment time		
E6	Shelf life of product		
E7	Market Demand		
E8	Supply chain traceability		
E9	IT/Automation		
E10	Service level requirements		
E11	Storage conditions required to ensure Quality		
E12	Efficient Transport facilities		
E4	Regulatory guidelines		

Using the dependence and power of driving calculated from the matrix, MICMAC is performed. MICMAC is used in figuring out the key variables in the system using dependence and driving power (Das, S.K., 2020). MICMAC develops a graph in which the factors are categorised based on its driving power, dependence and validate the variables considered in the model to infer conclusions (Ahmad, M., 2019).

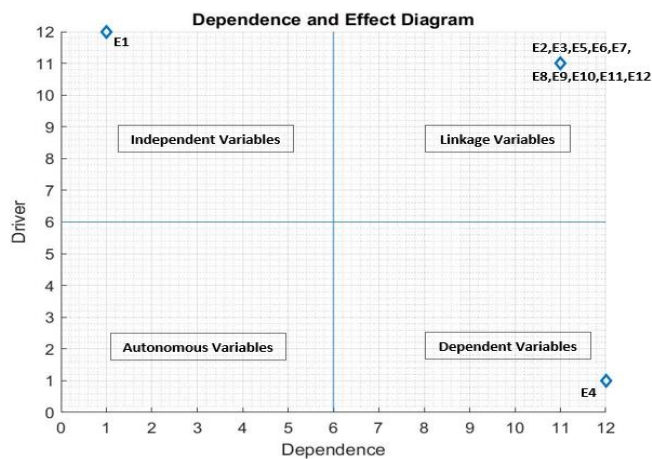


Figure 2: MICMAC Analysis

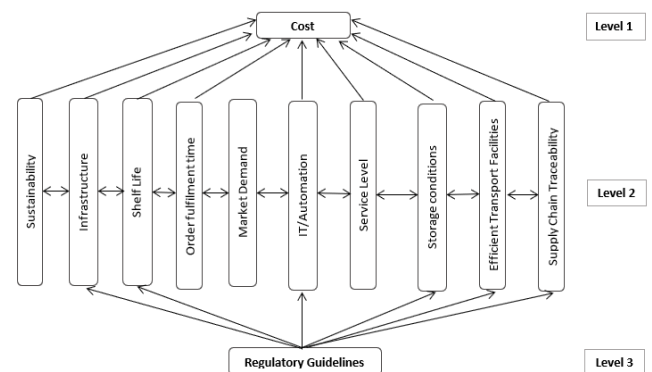
MICMAC is used to find out the key elements that drives the system. The variables are divided into four quarters with the help of dependence and driving power (K. Mathiyazhagan,2013). These are;

- Autonomous Factors-These variables possess less driving power and negligible dependence. These are kind of cut off from the system with very negligible links-1<sup>st</sup> Quadrant.

- Dependent Factors-This quadrant includes factors with strong power of dependence but less power of driving. These variables primarily depend on others (Khaba, S., 2018 and Lin, D.,2017)
- Linkage Factors-These are factors with strong power of driving and dependence. This set of variables are most influencing and are considered as unsteady factors which connects others. Any changes in these components will have an equal effect on themselves. This is represented in 3<sup>rd</sup> Quadrant.
- Independent Factors-This set of variables possess strong power of driving but less dependence. These variables need maximum attention and are key factors but these have least influence from other factors. This is represented in 4<sup>th</sup> Quadrant.

Results And Conclusions

12 factors significant in the supply chain and logistics of perishables were identified including cost, sustainability, infrastructure, shelf life, order fulfilment time, market demand, IT/automation, service level, storage conditions, efficient transport facilities, supply chain traceability and regulatory guidelines. These factors are compared to establish relationship among themselves and a structural model was formulated using ISM and MICMAC analysis. ISM analysis conducted on the identified factors led to the model given.



Results of the study indicate that shelf life/perishability is a driving factor in supply chain and logistics of perishables. But from the results drawn from the model, shelf life falls under linkage variable which has more driving power and a higher dependence. The hierarchy approach in the ISM modelling depicts that Cost (E1) is a

governing factor that affects the supply chain and logistics of perishables. Cost falls under Independent variable category and factors like these with higher driving power needs extra attention. Regulatory guidelines fall under dependent variable means this primarily depends on other variables or factors and has very less driving power compared to Cost.

Sustainability, infrastructure, shelf life, order fulfilment time, market demand, IT/automation, service level, storage conditions, efficient transport facilities and supply chain traceability emerged as-Linkage variables. These are influential for developing and maintaining an effective supply chain and these connect other factors in between.

- Autonomous Variables (1<sup>st</sup> Quadrant)-These variables shows weak power of driving and less power of dependence. Absence of autonomous variables in our model clearly implies that all factors considered in this research are crucial in modelling perishable supply chain.
- Dependent Variables (2<sup>nd</sup> Quadrant)-Regulatory Guidelines. This factor is a strong dependent but possess very weak power of driving.
- Linkage Variables (3<sup>rd</sup> Quadrant)- This set of factors exhibits strong driving power and strong power of dependence. 10 components fall under this category. All the factors have almost same driving power and dependence (11,11) This indicates that factors such as sustainability, infrastructure, shelf life, order fulfilment time, market demand, IT/automation, service level, storage conditions, efficient transport facilities and supply chain traceability need to be given equal importance and are strongly interrelated. Any changes or impact on these factors can affect all the considered factors.
- Independent Variables (4<sup>th</sup> Quadrant)-Cost falls in this segment. This variable shows Strong power of driving (12) and weak power of dependence (1) and need to be considered as the key player. This implies that stakeholders give a significant role for the different costs associated with the supply chain and logistics.

## 5.1. Limitations and Scope for further research

This study considered only 12 factors affecting the supply chain and logistics of perishables and is not exhaustive. Other variables need to be explored and added to this analysis for more accuracy. These 12 considered variables could be broke down into more details and analysis can be done on a microscopic view to understand the relationships among those. For E.g.; Cost can be considered as a factor with multiple variables under that such as warehouse cost, logistics cost, handling cost, sourcing cost, etc. This research focused on understanding the relationship between the factors, further these can be studied more extensively to arrive at strategies to enhance and make the supply chain more agile and efficient.

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