Modelling the Agri-Supply Chains

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Abstract
The efficient supply chain requires improved infrastructure support for various activities like input delivery, credit, procurement, reducing post-harvest losses, improved storage facilities including cold storages, setup of different processing units. Through this study an effort is being done to identify different variables that act as potential sources of inefficiencies in supply chain of tomato. The identified sources of inefficiencies are then further studied and modelled with the help of ISM Tool. Further, two suggestive practical models have been proposed to remodel the Supply Chains.

Keywords: Supply Chain Management, ISM, Inefficiencies, Agri-models

JEL Classification: Q11, Q19

Paper Classification: Research Paper

Introduction
“The concept of Supply Chain Management (SCM) originated in the early 1980s” (Oliver.R. K., Webber.M.D, 1982) and subsequently it gained tremendous focus all across the world. SCM is a chain of various processes or activities which makes the product and services available from the production point to consumption point. Supply Chain, as a process, involves the producers and their suppliers and also the functionaries like warehouses, transporters, distributors, retailers and finally the consumers (Chopra and Meindl, 2001). The efficient supply chain requires improved infrastructure support for various activities like input delivery, credit, procurement, reducing post-harvest losses, improved storage facilities including cold storages, setup of different processing units.

Supply chain channels for Tomatoes in India vary considerably by commodity and states, but they are generally very long and fragmented in nature. Tomatoes are highly perishable commodity so due care must be taken during handling and transportation phase throughout the
supply chain network. Tomatoes being highly perishable are mainly transported in wooden boxes and plastic crates. One plastic crate contains 20-25 kg of tomato and all crates are generally stacked in columns of 7 to 10 in the trucks. Cost of single crate varies from Rs120-160. There are many channels that are involved in the supply chain of tomato in India. The channels and supply chain partners vary from company to company and places also (as per the requirement).

Tomato supply chain involves logistics costs like loading-unloading cost, transportation cost, market fees, warehousing charges and commission charges. Before April-15, in India in Azadpur Mandi Delhi, commissioning agents were charging 6% commission from farmers but from 24-April-15 onward commission is taken either from retailers or consumers (http://www.apmcazadpurdelhi.com)

Through this study an effort is being done to identify different variables that act as potential sources of inefficiencies in supply chain of tomato. Further, two suggestive models have been proposed to remodel the supply chains.

**Literature Review**

Various researchers have studied about supply chains in general and supply chains of fruits and vegetables in particular. Fruits and Vegetable Sector is one of the dominant sector of Indian Economy. Issues related to post harvest losses and wastages and other factors impacting supply chain of fruits and vegetables, need to be identified so as to make proper planning and implement mitigation strategies (Saurav Negi and Neeraj Anand,2015). Losses in vegetables may reach 25% of total production also (Verma and Singh, 2004). According to Sharma and Singh (2011), at later stages of supply chain post-harvest losses in tomato is 23.19% while at producer level the losses are 15.16%. The losses at retail level in tomato is found as 8.03% and at the growers level it is found as 17.46% in the hilly regions of Uttarakhand. In India, mostly manual harvesting of tomato is carried out which may reduce produce loss but it is a time consuming process. Majority of distribution losses are due to damages at the transportation and storage stages. Distribution losses account for approx. 15-20% in India(Thirumalai and Sinha, 2011). The study carried out by Mwagike L,Mdoe N(2015) projected that most of the small scale tomato growers have to sell their produce to middlemen because of factors like distance from market and inaccessibility to market information. As suggested by K C Prakash (2014) direct procurement of tomato by the suppliers and training the workers for proper grading and packaging methods can solve the problems of sourcing in tomato supply chains. Rais M, Sheoran A (2015) highlighted various issues that affect supply chain of fruits and vegetables in India as lack of cold storages, less skilled labor, poor road connectivity, various participants, lack of technology adoption. Arumugam N et. al. (2010) proposed organic farming as one of the solutions and carried out Factor Analysis to identify major factors making the growers to participate in contract farming towards a solution to agri supply chain problems. Negi S. & Anand N (2015) carried out an extensive study and found various factors which pose challenge for supply chain of fruits and vegetables in India. To mention a few, the authors have highlighted cold chain facilities, Infrastructure availability, transportation, market accessibility, packaging etc. Various researchers have also presented different models or ways of identification and modeling of the factors impacting supply chain. Deepak Bhagat & U. R. Dhar (2012) revealed that correct information and timely support help the farmers to gain access to the markets. As is expressed by M.V. Durga Prasad, “modeling the supply chain helps in modeling the sensitivity of one factor against other factors.”

Present study is, therefore, an effort towards identification and modeling of factors which contribute towards inefficiencies in supply chain of tomato.
For that purpose various factors have been identified from literature support and also substantiated based on discussions with farmers, retailers, middlemen etc. The factors identified with their literature support are shown as below:

### Factors affecting supply chain of Tomato (Factors are defined in section 2.3 below)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Factors</th>
<th>Literature Support</th>
</tr>
</thead>
</table>

### Research Gap

Most of the studies highlighted or studied factors impacting any one or two aspects of supply chain. Therefore this study identifies a variety of factors impacting supply chain of Tomato that contribute towards inefficiencies. Also, hardly any study has used the tool of ISM (Interpretive Structural Modeling Technique) for modeling the factors in the sector of Fruits and vegetables supply chain, therefore this study is adopting this technique. Also, in this study some factors are such which in the context of fruits and vegetables are being discussed by very few researchers.

### Contribution of the Study

As per as the present market scenario, the price of tomato is fluctuating in a drastic manner from a minimum of (10 rupees per kg) to as high as (80 rupees per kg). Due to this uneven distribution of price, farmers and consumers suffer a lot. Supply chain plays a major role in price distribution as well as the availability of product in the market. In supply chain of tomato, middle man/intermediaries as well as infrastructural support plays crucial role. Apart from these, various factors like government support, transportation system, lead time uncertainty, availability of particular variety as well as the quality of availability of graded or ungraded product in market also impact the price of tomato in the market. Through the study an effort is made to work towards improving efficiency of supply chain by identifying the various factors that impact the efficiency of supply chain. Also, through this study an effort is made to find out the potential source of inefficiencies especially during distribution and transportation in supply chain of tomato. Further, a suggestive model is proposed to minimize the effect of above mentioned factors so that whole supply chain becomes sustainable. This will increase the overall efficiency of supply chain of tomato and will be a solution to all the pitfalls that exist in the present supply chain.
Research Methodology

Sample

For the purpose of primary data collection, Delhi Azadpur Mandi, Gazipur Mandi, Kesopur Mandi and Sonipat local market were approached. These markets were purposely selected considering the accessibility factor from the Institute of Researchers. Sample size for the study includes 50 farmers, 30 retailers and 15 commissioning agents.

Data Collection

Method of Data Collection

For primary data collection purposes, Delhi Azadpur Mandi, Gazipur Mandi, Kesopur Mandi and Sonipat local market were approached and supply chain participants like commissioning agents, retailers and other participants at various levels were interviewed with the help of a semi structured questionnaire Similarly, farmers coming to market for selling their produce were also interviewed with the help of semi structured questionnaire. Personal interview of about 50 farmers, 30 retailers and around 15 commissioning agents were conducted on one to one basis and information is collected. Some information related with the inefficiency of supply chain is also collected on the basis of informal but focused discussion with the farmers and retailers.

Secondary data was obtained from APMC websites and literature review.

Variables under Study

On the basis of discussions and interviews with the farmers, retailers, commission agents and review of literature, seven factors were identified, that affects the supply chain of tomato and lead towards inefficiencies in the supply chain. ISM methodology helped in identification and development of relationship between factors that impact the supply chain of tomato. Following factors were identified as potential reasons for inefficiencies existing in different channels of Tomato Supply Chain.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Factors</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Lead time uncertainty</td>
<td>Lead time is the time lag involved in between two consecutive activities of a supply chain. There are various types of disturbances involved in the Tomato Supply Chain, due to which lead times become uncertain. The disturbances may be due to uncertain climatic conditions (natural disturbances); Distance from the market; Strike, band, accidents; Truck curfew etc.</td>
</tr>
<tr>
<td>2.</td>
<td>Insufficient transportation facilities</td>
<td>There is insufficient availability of cold chain for Tomato; product is packaged in highly inefficient manner, which causes transportation losses.</td>
</tr>
<tr>
<td>3.</td>
<td>Distorted market situation</td>
<td>Uneven pricing of product, irregular availability of product, non-standardized variety of product available in the market makes the market situation distorted.</td>
</tr>
<tr>
<td>4.</td>
<td>Large no. of channel / intermediates</td>
<td>There are different levels of supply chain existing in the market for tomato, which involves a large number of intermediaries.</td>
</tr>
<tr>
<td>5.</td>
<td>Low responsiveness towards natural uncertainties</td>
<td>Supply Chain participants have poor risk assessment techniques for natural disasters and other disturbances and also poor risk management.</td>
</tr>
<tr>
<td>6.</td>
<td>Poor infrastructure</td>
<td>The supply chain participants faces lack of infrastructure facilities like market infrastructure, storage facilities, transportation facilities, packaging and carrying material etc.</td>
</tr>
<tr>
<td>7.</td>
<td>Poor technological adoption</td>
<td>Tomato Supply chain faces poor technological adoption because of poor technological awareness among participants and majority of participants belong to rural areas and being uneducated to less educated are quite reluctant to adopt new technology.</td>
</tr>
</tbody>
</table>
Statistical Tool and Data Analysis

Data and information obtained during study were analyzed with the help of Interpretive Structural Modeling (ISM) tool developed in 1970’s. “Warfield (1982b) has described ISM as a computer-assisted learning process that enables an individual or a group user to develop a structure or map showing interrelations among previously determined elements according to a selected contextual relationship” (Bhupender et. al.,2015) . This is a structured approach for identification and development of relationships among selected variables under study which are obtained from survey and review of literature.

ISM involves majorly 8 steps, which are explained below in brief (Ravi V. & Shankar R., 2005; Jayant A. and Mohd Azhar, 2014):

1. Variables identified that affect the supply chain are listed.
2. A contextual relationship is drawn among the variables identified in step 1 above so as to identify the interlinkages among the pair of variables.
3. Pair wise relationships among variables under consideration in the study, are indicated in this step through a Structural Self-Interaction Matrix (SSIM).
4. From the SSIM, next a Reachability Matrix is prepared which is then checked for the transitivity. The transitivity is an assumption used in ISM.
5. In this step, Iteration Matrix is obtained which shows different partition levels, for Reachability Matrix.
6. The transitive links are then removed from the Reachability Matrix and Digraph is made.
7. The digraph prepared as above is then converted into an ISM.
8. The ISM model is reviewed and necessary modifications if required are made.

To develop the Structural Self-Interaction Matrix (SSIM), four symbols viz. V, A, X, O, have been used to represent direction of relationship between two variables i and j.

V- Variable i leads to Variable j; A- Variable j leads to Variable i; X- Variable i and j leads to each other; O- Variables i and j are unrelated.

Results and Discussion

On the basis of interviews with the respondents and review of literature, seven factors were identified, that affect the supply chain of tomato. ISM methodology helped in identification and development of relationships between factors that impacts the supply chain of tomato.

Further, ISM tool is applied on the identified factors for the purpose of identifying contextual relationship between them. Then, SSIM, as reflected in Table 1, is framed for getting pair wise relationships among factors which affects the supply chain of tomato.
Table 1: Structured Self Intersection Matrix (SSIM) for barriers of supply chain of Tomato

<table>
<thead>
<tr>
<th>Elements</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
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<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>A</td>
<td>V</td>
<td>A</td>
<td>X</td>
<td>A</td>
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<td>V</td>
<td>O</td>
<td>V</td>
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<td>5</td>
<td>A</td>
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<td>6</td>
<td>A</td>
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</tbody>
</table>

In next step, reachability matrix will be developed. For this in the initial reachability matrix, format of cells is changed by substituting V, A, X, O by 1 or 0 (i.e. binary digits), as per the rules mentioned here (Muduli et al.2013):

“If (i,j) entry in SSIM is V; then (i,j) entry in Initial reachability matrix is 1 and (j,i) is 0
If (i,j) entry in SSIM is V; then (i,j) entry in Initial reachability matrix is 1 and (j,i) is 0
If (i,j) entry in SSIM is V; then (i,j) entry in Initial reachability matrix is 1 and (j,i) is 0
If (i,j) entry in SSIM is V; then (i,j) entry in Initial reachability matrix is 1 and (j,i) is 0”

To get, Final Reachability Matrix (Table 2) transitivity is incorporated from the initial matrix by adding 1* entries into the gap. “If a variable ‘i’ is related to ‘j’ and ‘j’ is related to ‘k’, then as per the concept of transitivity variable ‘i’ is necessarily related to ‘k’ “(Jadhav J.R et al.,2013)

Table 2: Final Reachability Matrix

<table>
<thead>
<tr>
<th>Elements</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>1</td>
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<td>1*</td>
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<td>7</td>
<td>1</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Iteration matrix (Table 3) is obtained by calculating Antecedent set which is obtained by calculating number of 1’s in row. Then intersection is calculated on the basis intersection of elements of Reachability set and Antecedence set. Level is assigned if the elements of Reachability set and intersection is same.
Table 3: Levels of Variables

<table>
<thead>
<tr>
<th>Elements(Pi)</th>
<th>Reachability Set R(Pi)</th>
<th>Antecedent Set A(Pi)</th>
<th>Intersection R(Pi)(^{\land})A(Pi)</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 3 5 6</td>
<td>1 2 3 4 5 6 7</td>
<td>1 3 5 6</td>
<td>I</td>
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<td>2</td>
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<td>7</td>
<td>1 2 3 5 6 7</td>
<td>4 7</td>
<td>7</td>
<td>III</td>
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</tbody>
</table>

Driving power is calculated by counting the number of 1’s in row whereas Dependence power is equivalent to number of 1’s in column. On this basis power rank has been assigned and shown in Table 4.

Table 4: Driving power and Dependence in Reachability Matrix

<table>
<thead>
<tr>
<th>Elements</th>
<th>3</th>
<th>5</th>
<th>6</th>
<th>1</th>
<th>2</th>
<th>7</th>
<th>4</th>
<th>Driving Power</th>
<th>Rank</th>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>I</td>
</tr>
</tbody>
</table>

Dependence Power: 7 7 7 7 6 2 1

Rank: I I I I II III IV

MICMAC Analysis

“MICMAC (cross-impact matrix multiplication applied to classification analysis) is done with the help of driving and dependence power of variables under study. This analysis classifies the variables into 4 different groups of Autonomous Variables, Dependent Variables, Linkage Variables and Independent Variables” (Kumar N. et al., 2013; Raj T. Shankar & Suhaib, 2008), as is shown in Fig.1.

- All the variables under study having weak driving power and weak dependence are being categorized as autonomous variables and lie in Cluster-I. No variable came in the category of autonomous variable as per this study.
- Variables which have very high dependence but weak driving power are categorized as Dependent Variables and are put in cluster II. In the study, one barrier named lead time uncertainty (1) lies in this category.
- Variables which have both strong driving power as well as strong dependence are categorized as Linkage Variables and are put in cluster III. In the study, inefficient transportation facilities
(2), distorted Market Situation (3), low responsiveness towards natural uncertainties (5) poor infrastructural support(6) lies in this category.

- The variables which emerged as having weak dependence but strong driving power are categorized as the Independent Variables and put in cluster IV. In our study large number of channel /intermediates.(4), Poor Technological adoption(7) lies in this category.

![Cluster Matrix](image)

**Figure 1. Cluster Matrix**

Inefficient transportation facilities, distorted market situations, low responsiveness towards natural uncertainties, poor infrastructural support are being categorized as linkage variables. None of the factors emerged as autonomous variable and one factor named Lead Time Uncertainty has shown very high dependency on other variables. As per the analysis, large number of channels/intermediates, and poor technological adoption have been identified as the variables having high driving power. Due care must be taken for managing large number of channels/intermediates, and poor technological adoption to improve supply chain efficiency. Also due to insufficient transportation mode, lack of adoption of technique, government support, uneven taxation system in different state, efficiency of supply chain gets affected. Overproduction, uneven availability of product in the market and wastage during transportation system also leads to price fluctuation. So proper techniques must be adopted during entire supply chain i.e. from farm to consumer to ensure the stability of price in tomato is maintained in the market so that there is a profitable situation for both consumer and producer.

To overcome the impact of these factors on supply chain of tomato, two models have been suggested. These models help in reducing the number of intermediaries in the supply chain and make supply chain more effective so that farmers are more benefitted.
Suggestive Model I:

Figure 2. Proposed model for minimizing the number of intermediaries in transportation channel of Tomato supply chain

In the existing supply chain model, farmers sell their products to village level aggregators, who sell the products to local wholesaler.

They sell the product to commission agent or organized retailers. Organized retailers also procure directly from farmer through contract farming. Agents buy the product and transfer it to wholesaler directly or may be through some other agent. Auctioneers involve into the buying agreement with farmers, to buy their whole or partial product. Then they send the product directly to wholesaler or through some other agent. Wholesaler sell the product either to retailer i.e. organized or unorganized or to the customers. In this way large numbers of intermediaries are involved in whole transportation and distribution channel of supply chain of tomato.

So to minimize the number of intermediaries, a model has been proposed. In this model it is suggested that proper communication between farmers is maintained at the local level with the help of mobiles and internet. It helps farmers in getting regular updates about prices as well as the demand of product in the market. Farmers transport their product to collection center, either with the help of truck or in small vans as per as their convenience. At collection centers, farmers get proper pricing of their product. Collection centers can be setup with the help of government agencies or co-operatives or private companies. All the centers are well connected with farmers as well as retailers so that prediction of demand as well as supply is performed in proper manner. These centers are equipped with the facilities of sorting, grading, and with preliminary processing of product. Centers are also equipped with small space for temperature controlled storage facilities and it can also be used as a warehouse. Centers then distribute the product to their chain of retailers from where consumer will buy the vegetables as per as their requirements. Poor quality tomatoes are sent back to collection center from where it is sold to cart vendors. In this way this model helps in minimizing the intermediaries throughout the chain.

Organized retailers like Big Bazaar, Spencer retail and many more are using almost similar model for their organized retail operations. Uttarakhand State Cooperative Federation (UCF) is also trying to develop model like this to benefit farmers.
Suggestive Model II:

Figure 3. Proposed model for minimizing the number of intermediaries

To minimize the intermediaries at farm level this model can also be utilized. In this model, all the partners of supply chain i.e. farmers, retailers and consumers are linked with the help of mobile network and internet. In this model, retailers consist of local vendors like cart vendors, companies involved in E-selling of vegetables and the societies committees. Interlinking between partners helps in accurate demand of product as well as supply of product. It helps in minimizing the number of intermediaries in local supply chain. Farmers directly sell their product to retailers and these retailers are directly linked with farmers.

Some online vegetable sellers like Sabzikart is using similar model for the procurement and selling of vegetable.

Conclusion

Large number of channels/intermediaries existing along all the channels of supply chain and poor technological adoption are the major factors that affect the transportation as well as distribution channel of supply chain. Because of large number of intermediaries starting from the collection of product from the farm level in the form of village level aggregators to local wholesaler to the commissioning agent, farmers are getting only 50-60% of price what consumers are paying in the market. Apart from these factors, poor infrastructure, insufficient transportation modes, distorted market situation i.e. availability of product, quality of product also affects the supply chain of tomato and causes huge price fluctuation in the market, due to which consumers suffer. So due care must be taken on this front with the help of farmers as well as government agencies to minimize the number of problems related with the supply chain to make it more efficient.

References


Authors’ Profile

Anupama Panghal is presently working as Assistant Professor in FBM&ED Department at National Institute of Food Technology and Entrepreneurship Development (NIFTEM), Sonepat, India. She is having 12 years of teaching and corporate experience. She has published 18 full length research papers in national and international journals of repute and presented papers at various national and international conferences. Her research interests include Agribusiness Management, Supply chain Management, Sustainability issues, Intellectual Property Rights (IPRs); Human Values and Ethics.

Bhanu Pratap is M.Tech in Food Plant Operations Management from National Institute of Food Technology and Entrepreneurship Development (NIFTEM), Sonepat, India. He is having 3 years of corporate experience. His research area includes Supply Chain Management, Operations management etc.

Shilpa Sindhu is presently working as Assistant Professor (Selection Grade) in School of Management at The Northcap University, Gurugram, India. She possesses 11 years of corporate and academic experience. She holds Ph.D in Business Administration and ASRB-NET qualified. She specializes in the area of Marketing with interest in Marketing, Retail Marketing, E-commerce, Consumer Behavior, Sales and Distribution, Entrepreneurship, Agri-Business Management. Her research papers have been published in various peer reviewed national and international journals and has presented papers at various national and international conferences in the areas of marketing, e-tailing, rural marketing, and economics.