Analytical Structural Model for Implementing Innovation Practices in Sustainable Food Value Chain

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Abstract. In the current scenario, sustainability is asserting a profound effect on the global food supply chain (FSC). It is driven primarily by growing consciousness of consumers who want healthy food and at the same time they demand that food production should not harm the environment. However, sustainability cannot be improved in isolation. It has to be a collaborative effort of all the players involved in the supply chain. This study is aimed at exploring the possibilities for agri-food sector of India to sustainably remunerate as good as its potential. From the perspective of a company engaged in production of an agri-food product, it is a challenging area of research to investigate into the decision making methodologies which suit the requirements of the stakeholders as well as generate a positive sustainable impact on the FSC. In this study, a detailed analysis is done considering the present sustainable practices followed and scope for future strategies which can be adopted by its production plant (PP). This is achieved with the aid of Interpretive Structural Modeling (ISM) technique, a multi-criteria decision methodology and fuzzy-MICMAC Analysis. A structured framework is obtained which shows the strength of the impact of each practice on the other. Using the result findings, it has been concluded that the PP must prioritize their efforts in taking measures for water reservation, pollution reduction, creating awareness among farmers and traders and adopting sustainable employment practices. This research work can, hence, steer the focus of the company in the direction of appropriately prioritizing their sustainability practices for achieving a sustainable supply chain.

Keywords: Sustainable Practices, Agri Food Supply Chain, Interpretive Structural Modeling, fuzzy-MICMAC Analysis.

1 Introduction

Recently, there has been a growing concern for implementation of sustainability practices in supply chain (SC) management. The focus is drifting towards long-standing sustainable development rather than short term growth and on balancing profitability and socio-environmental impacts. Some of the major reasons for the same are government regulations, increasing competition, increasing demand for sustainable products, increasing concern for depleting bio diversity, etc. [1]. In case of agri-food industry, the main drivers behind this adoption are industrialization of agriculture, food safety and quality concerns, government intervention, customer concerns, emergence of modern retailer forms and multinational corporations [2][3][4]. The changing consumption pattern and demand for food is also putting tremendous pressure on the food supply chain (FSC) members to embrace sustainability in its operations [5]. In general, an agri FSC network is structured in multi-level echelons such as the input suppliers, producers, intermediaries, processors, retailers and consumers. The FSC operations include procurement, production, storage, processing, marketing, distribution, food services and consumption [6]. The FSC configuration is quite complex due to the inclusion of characteristics such as product perishability, production seasonality and variability in quantity and quality of supply and traceability [7]. Although the agri-food industry has immense prospective for sustainability in terms of fulfillment of farmer's needs, employment prosperity, local growth, private enterprise, sustainable utilization and environmental impact, however, encompassing sustainability concerns in a FSC is all the more challenging due the complex and dynamic nature of the product in focus [8]. It is mainly because efficient policies have to be deployed according to the needs of the agri-food industry and subject to the constraints of cost-efficiency of operations, logistics infrastructure, access to resources, seasonal variability and regulatory conditions [9].A typical wheat SC involves movement of farm produce from farmer to the end consumer and therefore, the role of farmers in the overall sustainability is crucial.

In context of this, the research objective of the present study is to develop an integrated sustainable FSC framework that can be adopted in agri-food sector, particularly in the wheat milling sector, in order to cultivate a sustainable culture which is beneficial for all the members of the SC, in particular for the farmers. As the sustainability issues are industry specific as well as company specific, hence, case study of Delhi Flour Mill Company (DFM) based in National Capital Region, India has been taken into consideration. Since sustainability can only be attained with the support of all the stakeholders, therefore, a multi-criteria decision making approach is required for developing the analytical framework. Eight key emerging sustainable practices are identified by the decision body of the company for management of their SC. Adoption of these may result in enhancement of social well-being of farmers along with significant reduction of the total energy use, product waste, greenhouse emissions, environmental impacts, harmonizing of food safety policies and traceability systems, etc. Understanding the inter relationships between these practices and their mutual impact on each other is essential for their effective implementation. This is the core objective of the present work which has been accomplished through the use of ISM process and fuzzy-MICMAC analysis. Results of the same provide insightful implications for the company.

The rest of the paper is structured as follows: Section 2 gives a brief literature review. Section 3 presents an overview of the flour mill company and presents the list of identified sustainable practices. The methodology adopted is presented in section 4, and section 5 elaborates upon the result and draws useful implications. The conclusion emerging out of the study is summarized in section 6.

2 Literature Review

2.1 Sustainable food value chain

The changing consumption pattern and demand for food is putting tremendous pressure on the FSC members to embrace sustainability in its operations [10]. [11] discussed the importance of engaging consumers and highlighted the importance of co-operation among food manufacturers, retailers, NGOs, governmental and farmers' organizations. The study by [12] evaluated the critical factors for sub-supplier management in a sustainable FSC perspective. In case of developing economies, [13] addressed the issue of impact of sustainable SC practices on food safety assurance in Food firms. Irrespective of the above mentioned research, the dimension considering sustainability initiatives in FSC planning in Indian context still remains untouched which is the focus of the present.

2.2 ISM Methodology

The review of literature shows that ISM is extremely popular choice for identification of significant barriers [14] and enablers [15] in various industries. [16] employed ISM methodology to derive the dominant enablers for implementing sustainability initiatives in the Indian retail sector. [17] analyzed the potential barriers which would hinder the manufacturing organizations from embracing Industry 4.0 using ISM and fuzzy MICMAC. A number of researchers have contributed in the application of ISM methodology to delve into deeper understanding of implementation of sustainability practices in Agro SC. [18] evaluated the barriers for implementation of sustainability in Indian FSC.

3 Problem Description

3.1 Overview of the Supply Chain of Delhi Flour Mills

The Delhi Flour Mills Company Limited, part of DFM group, is a century old public limited enterprise. It is classified as non-government company and is registered at Registrar of Companies, Delhi. Fig. 1 provides the pictorial representation of their SC.

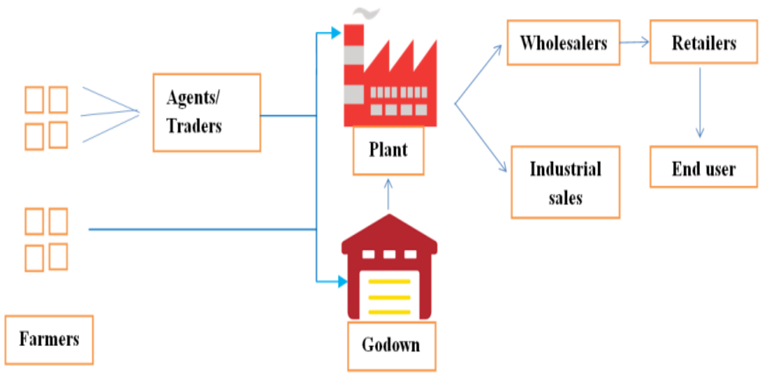

Fig. 1. DFM Supply Chain

3.2 Sustainability Practices of Delhi Flour Mills

Table 1. Present Sustainability Practices

S.No	Practices	Description
1	Alliance with social groups, projects or institutes for societal development.	Increasing sustainability awareness amongst all the members of supply chain.
2	Adoption of pollution reduction measures	Reducing pollution caused during all the stages of procurement, production and distribution.
3	Adoption of water conservation measures	Conserving water during all the stages of production.
4	Recyclable packaging	Ecofriendly packaging of raw material as well as final products.
5	Appropriate Quality Measures	Strict quality inspection during all the stages of procurement, production and distribution of wheat.
6	Effective measures for attaining a holistic sustainable SC	Proper handling, production and storage of wheat in ways that prevent food-borne illness, flour fortification, reducing waste, feed livestock, etc.
7	Adoption of Energy efficient measures	Providing work from home options to employees, using energy efficient equipments at the facility, organizing Skype interviews, improving the energy efficiency of the processes or equipments used, etc.
8	Innovative employment practices	Providing opportunities for staff training and education, conducting recreational activities, providing sustainable work environment, etc.

The company in an effort to abide by the sustainability regulations imposed by the government and pressure mounted by the stakeholders, has been involved in few sustainability initiatives which are briefly described in Table 1.

3.3 Objective of the Study

The problem faced by the company is that how to draw maximum benefits from these sustainable practices given the limitations of the company and the challenges it faces. There is scope of improvement in each of these initiatives but it must be done within the economic constraints. Thus, an in-depth analysis of the impact of each of these practices on the overall performance of the SC must be made so that right decisions can be taken at the strategic, tactical and operational levels. The analysis is carried with the aid of the ISM and fuzzy-MICMAC to attain the following objectives:

- To identify practices which would enable sustainability compliance in the flour mill.
- To rank the identified practices
- To map the relationships between the practices
- To highlight the most imperative practices.

4 Methodology

A prerequisite for ensuring sustainability across the multitier FSC is that the most effective solutions must be recognized by the stakeholders through a multi criteria decision making process. The methodology adopted involves data collection through interviews and structured questionnaires and data analysis using ISM methodology and fuzzy-MICMAC.

4.1 Data Collection

To understand and identify the key efforts made by the stakeholders of the mill towards sustaining high performance, a team of 6 decision makers (DMs) including the senior and junior functionaries were consulted. They were designated as Assistant General Manager (GM)-Wheat Management, GM-Business Operations, GM-Human Resources, GM-works production, Chief Financial Officers and the Company Secretary. Data collection stressed on the collection of the qualitative and quantitative data relating to the various aspects of sustainability initiatives undertaken by the mill and also the problems faced and prospects that lie ahead. The primary information was gathered through a structured questionnaire for soliciting responses from executives and senior and junior functionaries. The secondary information was collected from records of the company and also their official website. A list of sustainable practices presented in Table 1 in section 3.2, is prepared based on the information gathered through the data collection process.

Overview of steps of ISM as taken in this study is given below:

Step 1. Identify and define the factors

In this step, factors (sustainable practices) are identified by the team of DMs, as discussed in sec 4.1, which impact the main objective (of sustainable growth). The identified factors are listed in Table 1.

Step 2. Define the comparative/contextual relationship between these factors

Based on DM's opinions, contextual relationship is established between the 8 factors based on how one influences the other in attaining the objective.

Step 3. Construct the Reachability Matrix

Initial Reachability Matrix is constructed using the binary values representation of pairwise relationships among factors, where value '1' (or '0') at the $(i,j)^{th}$ entry of the matrix signifies that the i^{th} factor *influences* (*does not influence*) the j^{th} factor. Final Reachability Matrix, displayed in Table 2, is formed by considering all the transitivity's which means if $(i,k)^{th}$ entry and $(k,j)^{th}$ entry is 1 then $(i,j)^{th}$ entry will also be 1.

Table 2. Final Reachability Matrix

	F1	F2	F3	F4	F5	F6	F7	F8
F1	1	1	1	1	1	0	1	1
F2	0	1	1	1	1	0	1	1
F3	0	0	1	0	1	0	0	0
F4	0	0	0	1	0	0	0	0
F5	0	0	0	0	1	0	0	0
F6	1	1	1	1	1	1	1	1
F7	0	1	1	1	1	0	1	1
F8	0	0	0	0	0	0	0	1

Step 4. Obtain the Level partitioning

Hierarchical configuration is done by building reachability and antecedent sets from the FRM. Reachability set of practice F_i consists of practices F_j's which are reachable from or are affected by factor F_i, implying that $(i,j)^{th}$ entry of the matrix is '1' Antecedent set consists of practices F_j's which practice F_i gets affected by or is reached from implying that $(j,i)^{th}$ entry of the matrix is '1'. At each level *m*, a practice F_i is allocated level *m*, if its reachability set contained in its antecedent set. The corresponding i^{th} row and i^{th} column are eliminated from the matrix for the next level. These iterations are repeated till each practice is allocated a level. The 8 sustainable practices considered in the study are allocated levels in four iterations, out of which first and final iterations have been shown in Table 3**.**

Step 5. Developing ISM Model

Diagraph or directed graph is made as given in Fig. 2 in order to represent the hierarchical configuration. Nodes representing the various practices are placed as per the levels along with directed links between the practices.

Table 3. Level Partitioning

Practices	Reachability set	Antecedent set	Intersection set	Level
		Iteration 1		
1	1,2,3,4,5,7	1,6	1	
2	2,3,4,5,7,8	1,2,6,7	2,7	
3	3,5	1,2,3,6,7	3	
4	4	1,2,4,6,7	4	I
5	5	1,2, 3,5,6	3,5	I
6	1,2,3,4,5,6,7,8	6	6	
7	2,3,4,5,7,8	1,2,6,7	2,7	
8	8	1,2,6,7,8	8	I
		Iteration 4		
1	1	1,6	1	IV
2	2,7	1,2,6,7	2,7	III
3	3	1,2,3,6,7	3	II
4	4	1,2,4,6,7	4	I
5	5	1,2, 3,5,6	3,5	I
6	1,6	6	6	V
7	2,7	1,2,6,7	2,7	III
8	8	1,2,6,7,8	8	I

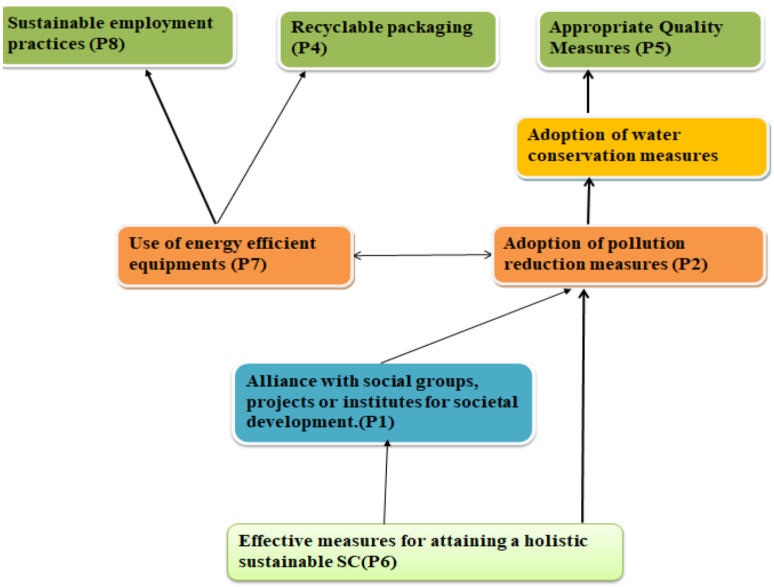

Fig. 2. ISM Hierarchal Model

4.2 Fuzzy-MICMAC Analysis

The major drawback of using ISM is that only binary values of 0 or 1 are considered and there is no option of determining the strength of the relationship between the variables (practices). It is assumed that when there is no linkage between variables, then it is denoted by 0 and when there is linkage then a value of 1 is used to denote this relationship. The fact that the relationship can be very strong, strong, weak or very weak is not considered. In order to overcome this limitation of ISM modelling, fuzzy-MICMAC is used for more precise analysis.

The following steps are used to carry out the fuzzy-MICMAC analysis:

Step 1: Construction of Binary Direct Relationship Matrix (BDRM).
. The initial reachability matrix is used to construct BDRM. In this step, the diagonal elements are considered as zero.
Step 2: Determination of Fuzzy Direct Relationship Matrix (FDRM)
In this step, fuzzy set theory is utilized to consider the additional possibility of relationship between practices. The possible values of reachability were taken as “0-No”, “0.1- Very low”, “0.3-Low”, “0.5- Medium”, “0.7- High”, “0.9-Very high” and “1-Full”. Based on these values the opinions of DMs are considered and the BDRM matrix is converted to FDRM.

Step 3: Obtaining fuzzy-MICMAC Stabilized Matrix
The FDRM matrix is multiplied repeatedly until the hierarchies of the driving power and dependence power stabilize [19], [20]. Fuzzy matrix multiplication generates another fuzzy matrix using the given below rule [21].

$$C = A \times B = \max k\,[\min(a_{ik}, b_{kj})] \text{ where } A = [a_{ik}] \text{ and } B = [b_{kj}]$$

Table 4. Stabilized Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	Dr P
F1	0	0.5	0.3	0.5	0.3	0	0.5	0.5	2.6
F2	0	0.5	0.3	0.5	0.3	0	0	0.4	2
F3	0	0	0	0	0	0	0	0	0
F4	0	0	0	0	0	0	0	0	0
F5	0	0	0	0	0	0	0	0	0
F6	0	0.5	0.2	0.4	0.7	0	0.7	0.7	3.2
F7	0	0	0.3	0.5	0.3	0	0.5	0.5	2.1
F8	0	0	0	0	0	0	0	0	0
De P	0	1.5	1.1	1.9	1.6	0	1.7	2.1	

Table 4 gives the stabilized matrix. The driving and dependence power of the practices are derived by summing the entries of the possibilities of interactions in the rows and columns.

Step 4: **Classification of factors**

In this step, the factors are classified into linkage, driving, autonomous and dependent factors based on their driving and dependence power.

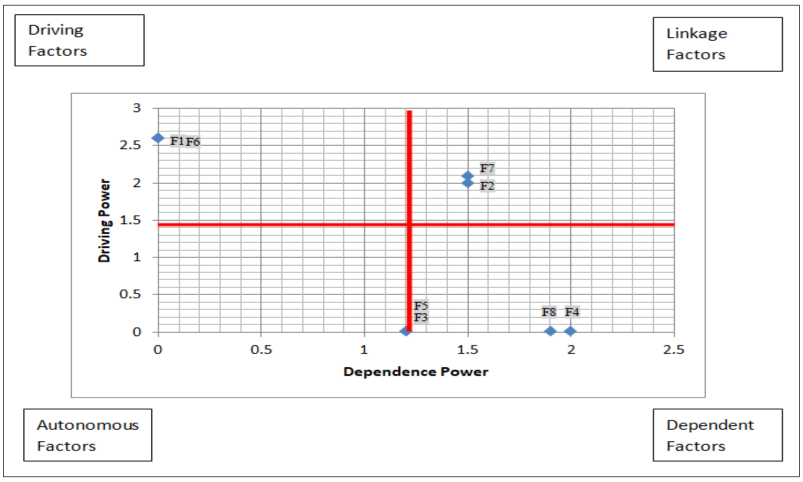

Fig. 3. Classification of Factors using fuzzy-MICMAC

- **Autonomous factors:** They have less driving as well as dependence power. They are not affected by the other factors nor do they affect the factors.
- **Linkage factors:** They have high driving as well as dependence power. They are not stable as any little variation in them affects the system.
- **Dependent factors:** They have high dependence and less driving power.
- **Driving factors:** They have high driving and less dependence power.

Fig. 3 shows the graphical representation of this classification.

5 Result Discussion

In ISM, "Effective measures for attaining holistic sustainable SC" is observed to be at the top level followed by "Alliance with social groups, projects or institutes to help the firm work towards social sustainability". It is further validated by the fuzzy-MICMAC analysis in which these practices have 'Driving' power 3.2 and 2.6, respectively, which is highest among the rest. As observed from Table 3, both these practices also have '0' 'Dependence' power. ISM provides the direction and order of the relationship between each practice and fuzzy-MICMAC provides a useful insight for DMs to understand the relationship between 'Driving' and 'Dependent' factors as classified in Fig 3. DMs can also comprehend the relative importance and interdependencies among all practices in order to map the detailed framework of all the practices and effect of their implementation on the SC.

Accentuating “Effective measures for attaining holistic sustainable SC”, would provide the much needed encouragement to the wheat industry in streamlining the process of sustainable growth of the SC. To implement this practice, focus needs to be laid on sustainable food safety, consumption and wastage measures which will automatically take care of related practices like “Adoption of pollution reduction measures”. Thus, there will be a significant reduction of the total energy use, product waste, environmental impacts, harmonizing of food safety policies and traceability systems and enhancement of social wellbeing. It also implies that for attaining sustainable SC, company will have to do “Alliance with social groups, projects or institutes to help the firm work towards social sustainability”. It will help the company to increase the sustainability awareness amongst all the members of the SC, viz, farmers, agents, facility, customer, etc. Creating sustainability awareness at the grass root level that is the second tier suppliers (or farmers) will have a vertical impact on the whole supply chain.

6 Conclusion

The current study attempts to present a prioritization model for sustainability practices that can be implemented in the wheat mil fuzzy-MICMAC ling sector with a case based study of DFM Company. The most crucial practices, as identified by the study, will help the company in addressing the sustainability concerns related to farmers and thus, accelerate the overall progress of the wheat SC to-wards sustainability. A multi criteria decision making technique called ISM has been utilized for the purpose of identifying the most imperative practice which helps in making rational decisions in a conflicting environment. It is based on graph theory approach which helps in reducing the complexities involved in the decision making process. The result obtained from it is reinforced using fuzzy-MICMAC analysis. Therefore, the framework proposed for attaining the desired sustainable FSC for the flour mill is not just a theoretical possibility but is practically feasible.

The inference derived from the study indicates that “Effective measures for attaining holistic SC” is the most pivotal sustainable practice. Company stakeholders must encourage investment in sustainable food safety, consumption and wastage measures. Also, association with social groups working in the same direction can turn out to be a major step while stepping forward on the ladder of sustainability.

Any new practice introduced by the company impacts all the decisions made at the strategic, operational and tactical level, therefore, the investments and efforts to be made in the redesigned FSC must initially focus on the most significant practices. Infusion of the most impactful practices into the SC network is sure to enhance the sustainable performance of the wheat milling sector. The framework provided by the study highlights the hidden dependencies between all the practices and provides a clear understanding of the areas which require urgent accountability. Accordingly, timely action and emphasis would help in attaining a sustainable value chain from farmers to consumers. The company may face many challenges and discover many new opportunities in their journey towards prudent and effective execution of these practices. A generalized FSC framework can be developed which will overcome the case-dependent nature of the present study and aid in upliftment of farmers from various agro-sectors.

Compliance with Ethical Standards

This is an independent and non-funded research study, thus, there are no potential source(s) of conflict of interests. Also, informed consents were taken from all the respondents of the questionnaire.

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