Conceptual Structure for Supply Chain Operational Performance Indexing in Food Industry: Using SCAR Modeling

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Abstract: Paper discusses the various internal characteristics of supply chain in food industry. The large number of product variety in the specified industry has led to the concept of clustering the industry into five major clusters viz. dairy products, cold storage products, perishables as fruits and vegetables, pulses, rice, wheat and grains and packaged ground powdered spices. Based on the clusters and supply chain characteristics indicator variables like sustainability, collaboration, agility and resilience (SCAR) are considered to develop this framework to determine the supply chain operational performance index. This is a unique concept considering these indicator variables to build the framework. The framework is supported using sample case examples in order to simulate and illustrate the functioning of this framework and operational performance index for individual clusters in the food industry.

Keywords **– Operational Performance Index, Supply Chain, Food Industry, Food Supply Chain.**

I. INTRODUCTION

In any industry in the current scenario, it is important that performance is benchmarked based on industry standards. A methodology to an approach for benchmarking supply chain operational performance is being attempted in this paper. Food industry has got many competition and forms the part of imperfect competition in the market consideration. There are few big players who has sub-vendors and they are small players, primarily there job is production and supply of the materials, information and funds. This forms the supply chain for which various efforts have made in past decade to imply a framework for to benchmark the performance of the supply chain. There are various models which are existing in the market to deal with the performance mapping. But the bottom line to provide an index considering only operational parameters are not available. (Gunasekaran et al., 2001) discusses that managers and companies appreciated benefits of SCM, competition also is increasing between supply chains than companies. Rather than recognition of SCM, lack of ability for developing metrics and effective performance measures will enable to understand the efficiency of the supply chain. Supply chain is also considered to an infinite function of variety of factors, but behavioural aspects of human in the supply chain. Therefore, there is a need to build up a model or framework which would provide an indexing to the performance parameters of the chain.

According to (Jagdev and Browne, 1998; Jagdev and Thoben, 2001; Tan, 2001) supply chain are responsible for whole of the product life, from material procurement to consumer. There should be coordination and collaboration in the chain to make it function properly with ease. (Tundys & Wiśniewski, 2018) states that the measurement of the chain can be done different contexts. It can be done to measure the sustainability or greenness of logistic system or a flexibility of the system. (Wang, Heng and Chau, 2007) indicates that performance indicators support supply chain management (SCM) goals and provides useful information on long-term decisions. Companies and its entities can improve their performance of the supply chain using the information and stay competitive in the market. In this paper, there are different clusters from the food industry which is taken to develop this framework. The clusters are: dairy products, cold storage products, perishables as fruits and vegetables, pulses, rice, wheat and grains and packaged ground powdered spices. Also the indicator variables which are unique in this model are agility, resilience, sustainability and collaboration. This framework is aimed to help middle level managers who is more concerned on the performance of the supply chain.

Initial part of paper discusses the literature related as per the available framework and figures how to measure the supply chain performance for companies. The following part details on the research methodology and answers to research problems indicate and how the framework which is proposed for the industry experts for implementation will be an efficient tool for their reference on the performance index. Then, illustration of the framework with a case example is also depicted in the last part for supporting the framework and make readers easy to understand and apply it in the food industry or similar industries.

II. LITERATURE REVIEW

(Gunasekaran et al., 2001) SCM measures for performance can be categorised into financial and non-financial. Management level decisions made by top management needs financial measures. Whereas operational information is used by low level management. There are few existing models which are gives enough exposure and provides ready references to higher level or top

management. (Najmi & Makui, 2013) discusses the existing models and have distinguished it into five different approach. On the process based approach, few literatures supports their model with SC processes and sub-processes along with Six-sigma concept. Basically, the roots of all this models are based on Balance Score Card Method, SCOR model, Hybrid of Balance Score Card and SCOR (Supply Chain Operations Reference) model on perspective approach. Further, the classification is based on Hierarchical Based Measurement Model of Breakdown / Aggregation Model. In this model measures are grouped in cells at the intersection of the planning level activity and supply chain level activity. In the fourth approach, six-sigma based measurement of the supply chain is observed to be used. Lastly, the author also discusses about the Uncertainty theory based model. He also discusses various techniques which are used for performance measurements. They are:

- Analytic Hierarchy Process (AHP)
- Simulation
- Data envelopment analysis (DEA)
- Delphi method
- Heuristic techniques based model
- Hybrid techniques based model

(Tundys & Wiśniewski, 2018) discusses about the performance measurements in green supply chain. In his paper, he has used the concept of PEST model. He considers environmental performance measurements in supply chain. In his framework, he has considered greening, reasons, suppliers, benefits, performance and barriers as the dimensions. Greening indicates waste reduction, eco-friendliness, and reduction in carbon footprint, product life cycle management, reverse logistics and green transportation channels. Reasons includes economical, legal, environmental policies, CSR, competitor. Suppliers included quality, price, reliability, flexibility, long term relationships, geographic proximity, environmental issues, economic dependency, personal relationships, IT and social responsibility. Benefit caters customer satisfaction, supplier's capabilities to innovate, fill rate, reduction of stock. Based on barriers, it can be categorized into financial costs, green investments, supplier's facilities, human skills, green induced changes, firm culture, top management commitment, knowledge, outsourcing, and involvement. (Gunasekaran et al., 2001) presents the framework based on the following metrics:

- "Metrics for planning: order entry method, order lead-time, the customer order path.
- Evaluation of supply link, evaluation of suppliers, strategic level measures, tactical level measures, operational level measures.
- Measures and metrics at production level: range of products and services, capacity utilization, effectiveness of scheduling techniques.
- Evaluation of delivery link, measures for delivery performance evaluation, total distribution cost.
- Measuring customer query time, post transaction measures of customer service.
- SC and logistics cost: cost associated with assets and return on investments, information processing cost".

SCOR model introduced in 1996 by the Supply Chain Council is a business process reference model framework consisting of metrics, technology features SC business processes and best practices. (Theeranuphattana, 2008) presents the SCOR model is based on five core processes: deliver, make, plan, return and source. The other performance attributes which were taken in the model was flexibility, reliability, responsiveness, asset metrics and cost. The metrics can be explained as:

- *"SC reliability:* The performance of the SC in delivering the correct product to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.
- *SC responsiveness:* The speed at which a SC provides products to the customer.
- *SC flexibility:* The agility of SC in responding to market place changes to gain or maintain competitive advantage.
- *SC costs:* The costs associated with operating the SC.
- *SC asset management:* The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of both the assets: fixed and working capital".

(Lambert, 2001) presents the "map model" framework that consists of:

- "Map the SC and identify where the key linkages exist.
- Use the customer relationship management and supplier relationship management process to analyse each link and determine where additional value can be created.
- Develop the customer and supplier profit and loss statements to assess the effect of the relationship on profitability and shareholder value of two firms.
- Realign SC processes and activities to achieve performance objectives.
- Establish non-financial performance measures that align individual behaviour with SC process objectives and financial goals.
- Compare shareholder value and market capitalization across firms with SC objectives and revise process and performance measures as necessary.
- Replicate steps at each link in SC".

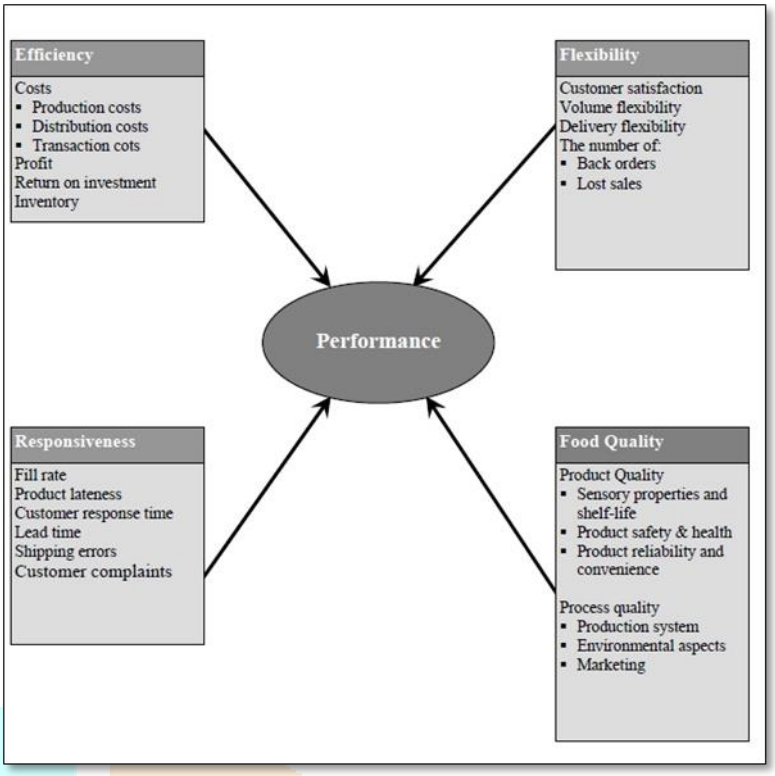

Fig. 1: Supply chain performance indicator by (Aramyan et al., 2007)

(Aramyan et al., 2007) discusses the performance indicators are categorized into four main categories: efficiency, flexibility, responsiveness and food quality. Fig. 1 provides the framework for the detailed performance indicators under each of the indicator variables. This may be used at organizational level as well as the supply chain level. Efficiency measures how well the resources are utilized. It also includes variables like costs, profit and ROI. Flexibility indicates the degree to which the supply chain can respond to a changing environment and extra-ordinary customer service requests. It may include fill rate, product lateness, customer response time, lead time, shipping errors, and customer complaints. Lastly, food quality is divided into product and process quality (Luning et al., 2002). Product quality is divided into product safety and health, sensory properties and shelf life, product reliability and convenience. Process quality consists of production system characteristics, environmental aspects, marketing.

(Chan, 2003) “SCM performance measurement approach which consists of qualitative and quantitative measures. Quantitative measures are cost and resource utilization and qualitative measures are quality, flexibility, visibility, trust, and innovativeness. The quantitative factor cost can be measured considering distribution cost, manufacturing cost, inventory cost, warehouse cost, incentive cost, subsidy, overhead cost, intangible cost and long term cost. Resource utilization means labor, machine, capacity, energy resource utilization and performance measurement”. In terms of time based quality measures, customer response time, lead time, on-time delivery, fill rate, stock out probability and accuracy are considered. “Flexibility measurement metrics are divided into input, process, output and improvement categories. Input category is measured by labour and machine flexibility. Process flexibility is presented as material handling flexibility, routeing flexibility and operation flexibility. Output flexibility is presented as volume flexibility and mix flexibility. Delivery flexibility and improvement are divided into modification flexibility, new product flexibility and expansion flexibility. Visibility is measured by time and accuracy. Trust is measured by consistency, which means the percentage of late or wrong delivery to the next tier which leads to an inconsistent supply. Innovativeness is presented as a new launch of product and new use of technology”.

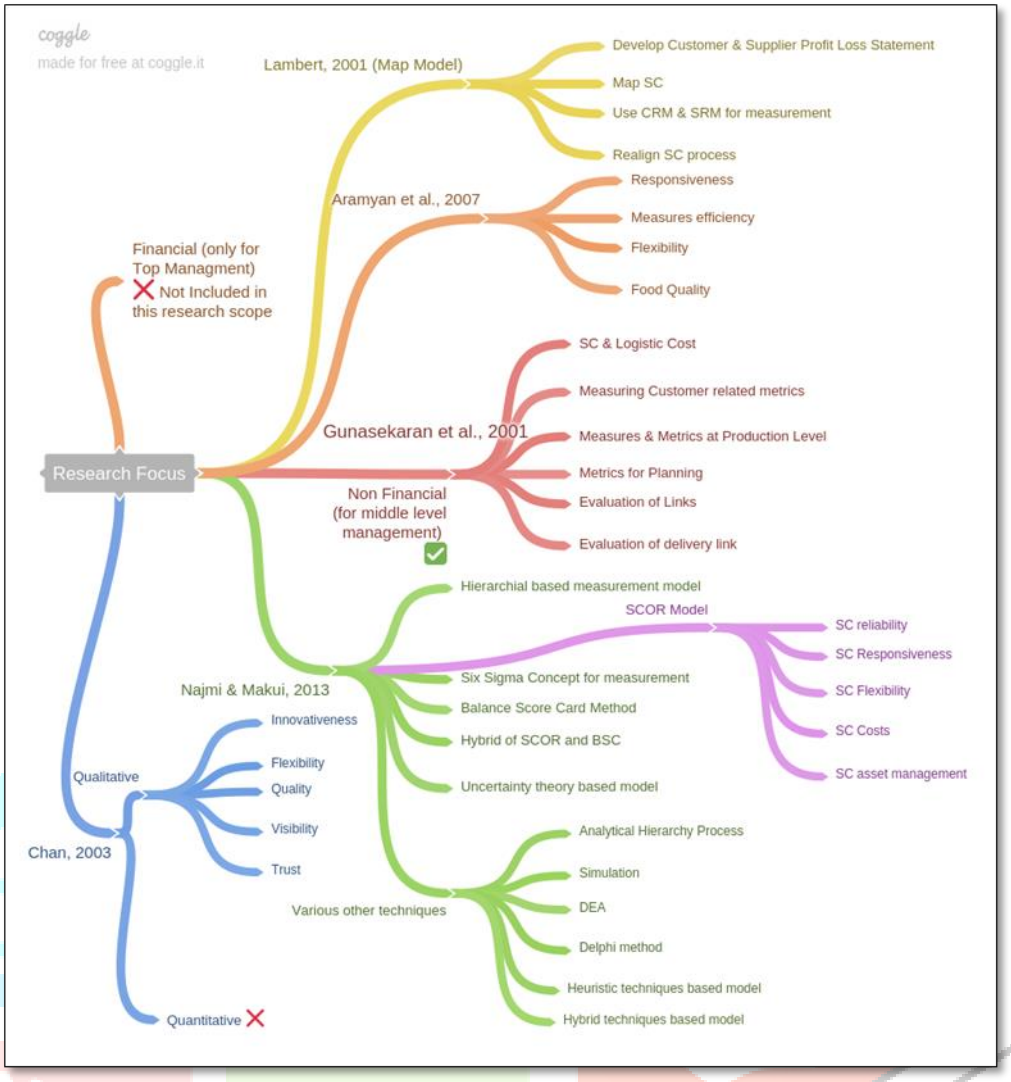

Fig. 2 Major Observations from Literature Review using Coggle diagram

III. PROBLEM ANALYSIS

The research of the literature indicates that the following are the problems which exist in the Food Supply Chain for performance measurement.

- What factors influence SC performance?
- What are the current models or framework to measure performance of the chain?
- How SCM framework can be developed for to benchmark performance of Supply Chain in food industry?

IV. RESEARCH METHODOLOGY & PROPOSED MODEL FRAMEWORK

4.1 Research Objective

- To find out the factors which influence SC framework from the literature using mind mapping tool i.e. Coggle diagram
- To depict the drilled down sub-factors which are closely related to the factors
- To draw the conceptual framework for the supply chain operational performance index and illustrate using case examples.

4.2 Research Methodology

The Coggle diagram in Fig. 2 clearly indicates the observations from the literature. It can be inferred that authors have suggested models considering financial implications and non-financial implications. Literature gaps are still in context of measuring operational performance of the supply chain. Here, the concept of four indicator variables are considered i.e. Sustainability, Collaboration, Agility and Resilience (SCAR) of the supply chain. It is attempted to link the operational performance of supply chain to these internal characteristics of supply chain. The characteristics are further drilled down to find out the sub-factors which defines the indicator variables. Based on the sub-factors, the frame work is designed in a tabular matrix along-with various clusters catered in Food Supply Chain (FSC). The framework is illustrated with a similar case example among the stated cluster in the framework to arrive at scalar measure to define the Operational Performance Index (OPI) of Food Supply Chain based on Agility, Resilience, Sustainability and Collaboration. The OPI obtained from the framework is also attempted to fit in with learnings from

BCG growth-share matrix with ROI and OPI in x and y axis respectively. This would finalize the respective supply chain as Stars, Cash Cows, Dogs or Question Mark. The chain can be depicted in the four quadrants for simplification or ease of understanding of this OPI.

4.3 Understanding the Indicator variables

In the model framework, we have considered four indicator variables which are sustainability, collaboration, agility and resilience. Sustainability in a supply chain is taken as the function of seasonality, adulteration of food items in the chain, legal compliances which involves around of the chain, organization culture and environment. In food supply chain, seasonality of food is the most important thing. If the consumers are consuming based on seasonality of food items, it makes the supply chain more resilient and sustainable. Adulteration means any vulnerability in food supply chain. If the food supply chain is found to be adulterated then, it forms an unsustainable supply chain. Legal compliances which are suggested for the preservation and storage of food while in transit or at any stakeholders of the supply chain makes the supply chain sustainable. Hence, this can also considered to be as a metric to define the sustainability of the food supply chain. Organization culture and environment are also positively correlated to sustainability in which culture of the firm defines the approach which it takes for handling of food items for the sustainable development of the society. A good sustainable business always reduces risks in the supply chain and mitigates inorder to comply with the legal compliances. Food supply chain also considers environment for sustainable growth of the chain. Food grown by farmers should be utilized by consumers. But in this modern era, consumers are duly considered that their food is organic and had been grown without causing harm to environment. Food quality is also determined by the method adopted by producers for farming in agri-business, dairy business, etc.

(Matopoulos, Vlachopoulou, Manthou, & Manos, 2007) discusses that collaboration means enterprises and organizations working together beyond the normal commercial relationships. It also indicates that operating alone is not sufficient to resolve common problems and to achieve the desired goals. Supply chain collaborations includes the following activities of the supply chain which is commonly sighted in most of the literature, viz. procurement, inventory management, product design and development, manufacturing, order processing, transportation and distribution, sales, demand management, customer service. Collaboration brings out several benefits associated with all the activities of the supply chain. In this paper, we have considered four dimensions of collaboration which is mostly sought in food supply chain activities. They are planning, geographical presence, partner's intelligent quotient and partner's emotional quotient. Selecting the behavioral part as the dimensions of the collaboration provides more information about the supply chain performance index.

(Aggarwal et al., 2007) presented that SC-agility be influenced by the ensuing: cost reduction, customer's satisfaction, improved quality, speedy delivery, introduction of fresh products, improvements in service level and reduction in lead time. Agility of the supply chain is also defined as how fast chain responds to changes in environment, its accessibility, its ability to take correct decisions during the change, promptness of the reply and its flexibility in terms of responding to the change. Supply chain agility is the measure of how companies adapt to these changes and then how fast it is able to achieve it. Measuring the supply chain agility can be taken from these various dimensions of Agility to construct the model framework. Agility is also the common measure for every SC manager.

(Pourhejazy, Kwon, Chang, & Park, 2017) discusses that supply chain resilience has received wide attention among both researchers and practitioners. He defines resilience as "the capacity for an enterprise to survive, adapt, and grow in the face of turbulent change". Measurement of resilience is taken here as the function of information flow, operational flexibility, market response and intermediaries relationship. Information flow will improve on the improved warning systems which can be used to reduce the risk associated in the chain. Flexibility is a complex multidimensional concept, difficult to summarize. It can be defined as an attribute of a system technology for coping with the variety of its environmental needs. Operational flexibility can be defined as systems readiness to cope up with any changes (product, volume or mix) at any node of the supply chain from producers to consumers. It provides SC managers a tool to monitor the changes which affects the operational performance of the supply chain. Partner's IQ and Partner's EQ are very subjective terms which may vary from one employee or expert cognitive ability for rating. But behavioral aspects of relationship of each stakeholders and IQ and EQ of intermediaries do affect the performance of the supply chain especially in food industry where IQ and EQ are most important dimension for the resilient supply chain.

Fig. 3 indicates the formation of Operational Performance Index using the four indicator variables and represents the same in Venn diagram. Fig. 4 discusses the inter-relationship of the indicator variables and its sub-factors or dimensions which have been catered in the model framework development. There are few dimensions which are related to two or more indicator variables. This inter-relationship diagram will help SC manager and experts to validate their understanding on the dependent variables from the dimensions identified in this paper. There are few more dimensions which are not catered and this forms the limitations of the papers and the conceptual framework being developed here. The bold lines represent the considerations made in the framework and the dotted lines represents the possible inter-relationship which can be made out by the experts, but are not considered in the model framework.

Fig. 3 Indicator variables considered for OPI framework

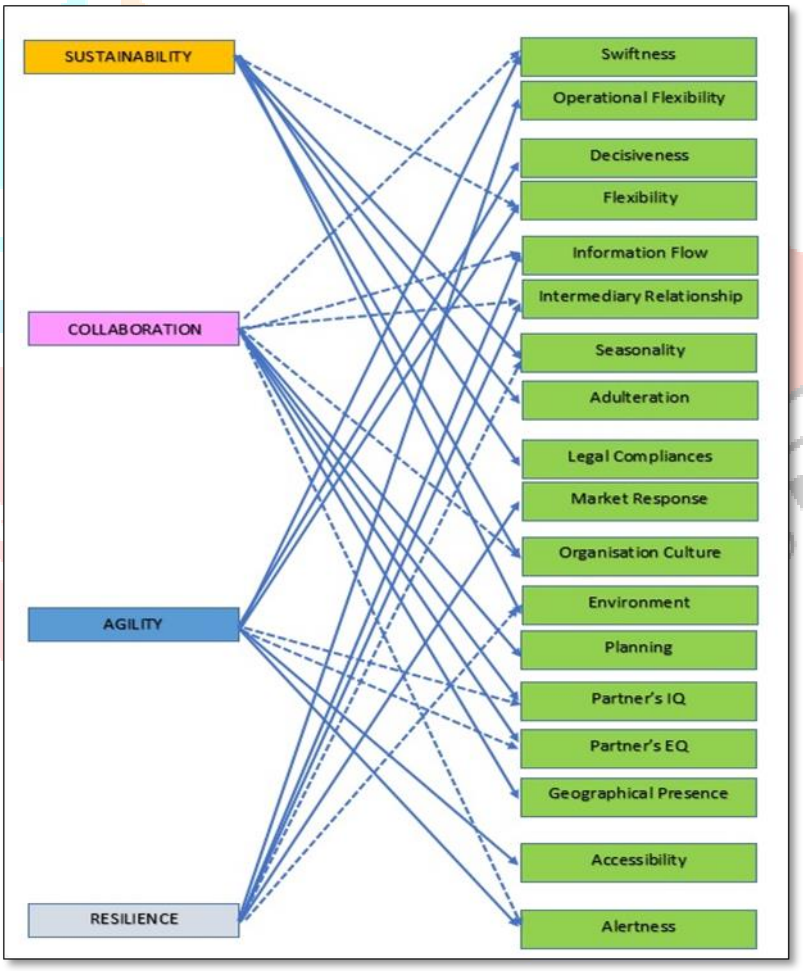

Fig. 4 Inter-relationship of Indicator variable with sub-factors considered for formulation of SCAR Model

4.4 Mathematical Representation

The mathematical representation of the model framework developed here are represented here for SCAR model.

For Sustainability: $\alpha = (W_f*A+ W_f*B+ W_f*C+ W_f*D+ W_f*E) + k$ (1)

Where α is termed for sustainability and k is function of $f(x_i)$ which is to be decided by functional owner in-case of any other parameter which are missed in this framework may be considered. A,B,C,D,E are the dimensions under sustainability and W_f is considered to be weighted factor.

For Collaboration: $\beta = (W_f*F+ W_f*G+ W_f*H+ W_f*I) + k$ (2)

Where β is termed for collaboration and k is function of $f(x_i)$ which is to be decided by functional owner in-case of any other parameter which are missed in this framework may be considered. F, G, H, I are the dimensions under collaboration.

For Agility: $\mu = (W_f * J + W_f * K + W_f * L + W_f * M + W_f * N) + k$ (3)

Where μ is termed for agility and k is function of $f(x_i)$ which is to be decided by functional owner in-case of any other parameter which are missed in this framework may be considered. J, K, L, M, N are the dimensions under agility.

For Resilience: $\Omega = (W_f * O + W_f * P + W_f * Q + W_f * R) + k$ (4)

Where Ω is termed for resilience and k is function of $f(x_i)$ which is to be decided by functional owner in-case of any other parameter which are missed in this framework may be considered. O, P, Q, R are the dimensions under resilience.

Inorder to calculate the Operational Performance Index of the supply chain, we need to find the summation of all the indicator variables.

Operational Performance Index **(OPI) = α+β+μ+Ω** **(5)**

Equation 5, gives the final model to calculate the operational performance index of the supply chain.

Inorder to calculate the weighted factor $W_{f,}$ use the below table:

Table – 1: Weighted factor calculations

Weightage	Indicators	Multipliers
0-2	Low	0.5
3-5	Medium	1.5
5-7	High	3
8-10	Very High	5

4.5 Model Framework & Illustration

Table – 2 gives tshe model framework for SCAR model, various clusters as dairy products, cold storage frozen products, perishables like vegetables and fruits, pulses, rice, wheat and grains, and packaged ground powdered spices is considered and indicator variables as discussed earlier in the section are modeled. Table 3, provides the values which are to be given by SC manager or experts using this framework to monitor their performance in food supply chain. The range of the values are given between 0 to 10 for each of the dimensions under each of the indicator variable.

Table - 2: Model Framework for OPI in food supply chain

OPERATIONAL PERFORMANCE INDEX (OPI) OF FOOD SUPPLY CHAIN																							
	Sustainability (α)						Collaboration (β)					Agility (μ)						Resilience (Ω)					
Cluster	Seasonality	Adulteration	Legal Compliances	Organisation Culture	Environment	α = (Wf*A+ Wf*B+W f*C+Wf* D+Wf*E)	Planning	Geographical Presence	Partners IQ (Intelligent Quotient)	Partners EQ (Emotional Quotient)	β = (Wf*F+ Wf*G+W f*H+Wf* I)	Alertness	Accessibility	Decisiveness	Swiftness	Flexibility	μ = (Wf*J+W f*K+Wf* L+Wf*M +Wf*N)	Information Flow	Operational Flexibility	Market Response	Intermediaries Relationship	Ω =(Wf*O+ Wf*P+W f*Q+Wf* R)	OPI = α+β+μ+Ω
	A	B	C	D	E		F	G	H	I		J	K	L	M	N		O	P	Q	R		
Dairy Products																							
Cold Storage Frozen Products																							
Perishables – Fruits & Vegetables																							
Pulses , Rice , Wheat and Grains																							
Packaged ground powdered Spices																							

Table –3: Rating of Clusters based on Indicator Variable to determine the OPI

Table for Rating of Clusters based on Indicator Variable to determine the OPI																		
Values (Based on % the values will be selected by user to select the values of A, B, C,.. to find the Operational Index Value for each of the cluster)	Alertness	Accessibility	Decisiveness	Swiftness	Flexibility	Information Flow	Operational Flexibility	Market Response	Intermediaries Relationship	Seasonality	Adulteration	Legal Compliances	Organisation Culture	Environment	Planning	Geographical Presence	Partners IQ (Intelligent Quotient)	Partners EQ (Emotional Quotient)
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
100%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
80 - 99%	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
60-79%	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
49 - 59%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Below 49%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table – 4: Illustration of the model framework with simulated numbers

OPERATIONAL PERFORMANCE INDEX (OPI) OF FOOD SUPPLY CHAIN																					
Cluster	Sustainability (α)					α = (Wf*A+ Wf*B+ Wf*C+ Wf*D+ Wf*E)	Collaboration (β)				β = (Wf*F+ Wf*G+ Wf*H+ Wf*I)	Agility (μ)					μ = (Wf*J+ Wf*K+ Wf*L+Wf*M +Wf*N)	Resilience (Ω)				Ω =(Wf*O +Wf*P+ Wf*Q+ Wf*R)	OPI = α+β+μ+Ω
	Seasonality	Adulteration	Legal Compliances	Organisation Culture	Environment		Planning	Geographical Presence	Partners IQ (Intelligent Quotient)	Partners EQ (Emotional Quotient)		Alertness	Accessibility	Decisiveness	Swiftness	Flexibility		Information Flow	Operational Flexibility	Market Response	Intermediaries Relationship		
	A	B	C	D	E		F	G	H	I		J	K	L	M	N		O	P	Q	R		
Dairy Products	8	5	7	5	8	131	4	5	8	7	82	8	7	4	4	4	79	10	8	5	5	120	412
Cold Storage Frozen Products	8	8	7	7	5	137	5	5	7	8	76	8	7	4	4	4	79	8	10	5	5	120	412
Perishables – Fruits & Vegetables	8	8	5	5	5	125	4	4	4	8	58	10	8	4	4	4	108	7	8	7	7	103	394
Pulses , Rice , Wheat and Grains	8	8	5	5	5	125	4	4	8	8	92	10	8	4	7	4	123	8	8	7	7	122	462
Packaged ground powdered Spices	8	8	8	8	8	200	8	7	8	4	107	4	8	7	7	4	94	8	8	5	5	110	511

Based on Table-4, we see that the experts or SC manager will provide data based on their cognitive ability and judgement of the supply chain at each nodes of the chain. Once the values are given using the table-3 we can arrive at index for each clusters and for each indicator variable and find out the final operational performance index using the formula stated under section 4.4. Here, we see that dairy products, and cold storage has same OPI, however, the values of sustainability of dairy product is less than cold storage frozen products. This differentiation of index value for each of the indicator variable also helps us to understand the supply chain of each of the cluster too. The final OPI value obtained is analyzed matrix similar to learnings from BCG matrix with OPI in y-axis and return on investment (ROI) in x-axis.

4.6 Operational Performance Index and ROI fit in learnings from BCG matrix

BCG growth share matrix gives the framework given by Boston Consulting group. In this framework to arrive at the final conclusion of the performance of the supply chain cluster, considering the BCG matrix gives the results based on the classification. The cluster will be arranged under four quadrants which is named similar to BCG matrix. Since the model framework for arriving at operational performance index is based on intrinsic characteristics of supply chain, the business intrinsic characteristics will satisfy the framework for its practical use in the industry. In this matrix return on investment (ROI) will be considered to be in x-axis which will be based on industrial standards and will be categorized here for easy referencing into two categories i.e. either clusters with high ROI or low ROI and OPI will be kept in y-axis where the same method is followed. However the range of the OPI will segregate it to be in high or low. The range of the OPI values obtained should be classified so as to fulfill the conditions similar to illustrated in BCG framework. The range is defined as following:

- OPI values between 0 – 400 as **low**
- OPI values of 400 and above as **high**

Thus, the final result obtained based on ROI and OPI considering the BCG matrix will define the firm's supply chain operational performance in following four categories in each of the four quadrants as stated in the fig. 5.

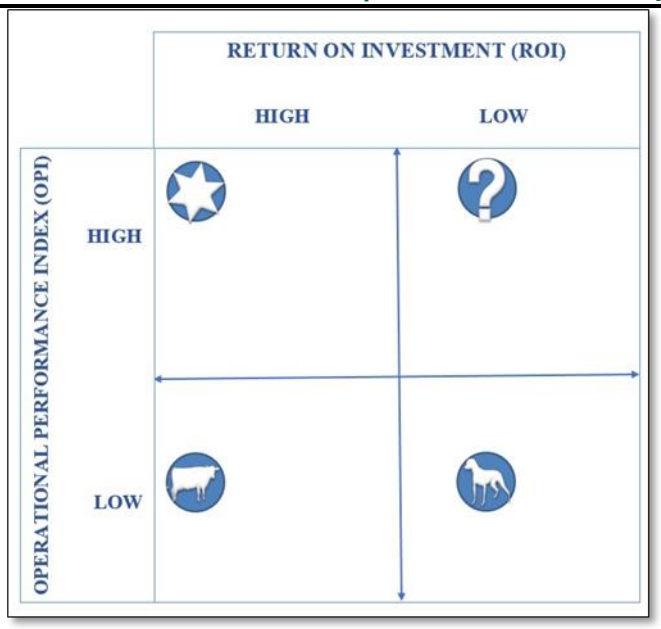

Fig. 5: ROI and OPI matrix

V. CONCLUSION

The model framework for the calculation of supply chain operational performance index will help food supply chain to provide an index based on supply chain performance. The measures based on the indicator variables will give a clear indication on the supply chain performance. ROI and OPI matrix framework provides a sound measure for the enterprise performance of their supply chain activities. There are few limitations which can be catered in future scope of study which includes the dimensions selected under each of the indicator variables. Inter-relationship of the dimensions under each of the indicator variables are not catered in this model which can be future scope in which researchers can utilize the inter-relationship mapping shown in fig. 4 for more detailed mapping of the inter-relationship of the dimensions under each of the indicator variable. Operational performance index of the food supply chain can be used for various other clusters of the supply chain and enterprise wide activities and would give index considering the operational performance of the firm. This would help SC managers to analyze and improve their performance in context to dimensions where there is lag and in which the performance can be improved.

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