Proposal of a Framework to Assess the Supply Chain Performance in the Agri-food Sector

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Keyword: Framework, Supply Chain, Performance, Composite Index.

Abstract: Companies need to excel in many areas to achieve a competitive advantage. Supply chain management is critical for a company's overall performance. It is therefore crucial that organizations measure the performance of their supply chains in order to define strategies that contribute to maximize the impact of their operations. This paper aims to propose a novel framework for assessing and monitoring the supply chain performance of companies of the agri-food sector. The framework consists of six steps to evaluate the companies supply chain performance. The linear aggregation technique is suggested to aggregate indicators into a unique value giving rise to a composite index considering five dimensions. The proposed framework can be used as a valuable instrument for the monitoring of supply chain performance of agri-food companies.

1 INTRODUCTION

The supply chain can be defined as a value system, made up of organizations that are connected together from the first stage of production up to the point of consumption, with the overriding objective of creating value along the chain (Porter, 1996). It represents a complex network of industrial plants and organizations with distinct, and often conflicting, objectives (Simchi-Levi et al 2003). Supply chain management (SCM) is a strategic management tool that seeks to raise the competitiveness and the profits of companies by increasing customer satisfaction levels (Christopher, 1992).

Christopher (1992) argues that SCM is not just a new management fad, but something that can be used as a tool for competitive differentiation. Mertz (1998) goes further, citing examples of quantitative benefits: a reduction in stocks of 50%, a reduction in the total chain cost of 20%, an increase in correct deliveries of 40% and a reduction in lead time of 27%. He also cites qualitative improvements, such as technical and organizational restructuring, improvements in capabilities and relationships, and transference of technology and knowledge between members.

The competitiveness of companies and the economy means that all its agents must reach levels of performance which are in-line with the expectations of the markets and their clients. In this context, metrics and measures of performance become essential for managers in their decision making when it comes to logistics operations and continuous improvement of the service supplied to the customer along the supply chain (Beamon, 1999; Gunasekaran et al 2001).

However, measuring performance in supply chains is difficult for additional reasons, especially when looking at numerous tiers within a supply chain (Gunasekaran et al 2004).

The creation of a Performance Management System (PMS) is primarily aimed at measuring the right things at the right time, in such a way that actions can be taken in a useful time frame. The metrics developed by the system should supply information to the various areas, always taking care to avoid duplication of information and to include the most relevant metrics. Producing good performance metrics and measures, opens the way for continuous improvement in the global performance of the organization (Gunaskeran et al 2001).

The main objective of this article is to propose a framework to assessing and monitoring the supply chain performance of companies of the agri-food

Miguel D. F. Ferreira L. and Arantes A..
Proposal of a Framework to Assess the Supply Chain Performance in the Agri-food Sector.
DOI: 10.5220/0005280304010406
In *Proceedings of the International Conference on Operations Research and Enterprise Systems* (ICORES-2015), pages 401-406
ISBN: 978-989-758-075-8

sector. The proposed framework consists of six steps, where linear aggregation technique is used to aggregate indicators into a unique value, giving rise to a composite index that reports the overall supply chain performance.

The article is divided into four sections. This section seeks to provide an introduction to the topic and define the objective of the study. The second section presents a literature review on agri-food supply chain and performance measurement in supply chains. Section 3 presents a model for evaluating the supply chain performance of agri-food companies. Finally, the main conclusions of the study are drawn in section 4.

2 LITERATURE REVIEW

Over the last years the agri-food sector has been confronted with a wide range of challenges, meaning that it has been, and will continue to be forced to provide effective responses for companies to be able to carry on business (Rajurkar and Jain, 2011).

2.1 The Agri-food Supply Chain

The agri-food supply chain is a chain producing, transforming and supplying agricultural and/or vegetable products at the same time as maintaining a flow of information between the various members. This type of supply chain is notably different due to: a) the nature of the production, being based on biological processes, as such being more susceptible to variations and to risk; b) the nature of the products, with specific characteristics, for example being perishable; c) consumers' behaviours and attitudes in relation to food safety, environmental protection and animal welfare.

Generally speaking we can distinguish between two types of agri-food supply chain: a) supply chains for fresh produce, such as fresh vegetables, flowers and fruit; b) supply chain for processed products, such as tinned vegetables or deep frozen vegetables. The agri-food supply chain has many identifying features that distinguish it from other types of supply chain. Among those the following can be highlighted:

- Seasonality of production;
- Special conditions necessary for storage and transport;
- The quantities processed and final product quality are dependent on biological variations, seasonality, weather conditions, pests and other biological maladies;
- Governmental laws that cover environmental protection and food safety;
- Product characteristics, such as flavour, odour, colour, size and appearance;
- Value added to the products, as is the case for example with ready-to-eat food;
- Product security: a growing concern by consumers with the means of production and processing of agricultural products;
- The quality as perceived by the consumer: targeted marketing campaigns are able to emphasise the quality of the products.

Recent studies show that the agri-food supply chain is in constantly evolving (Aramyan et al 2007; Fritz and Schiefer, 2008; Rajurkar and Jain, 2011; Van der Vorst, 2000). One of the main changes is the adoption of new strategies by producers. Their viewpoint is no longer dominated by questions of production but has shifted to focus on the market, which has implied an increase in the information flows in the chain. Another change of note in the sector relates to innovation and the development of new products. All these changes are the result of consumer demand for quality and variety in the products. In contrast, there is a growing concern among consumers in relation to food safety and the conditions under which the products are processed.

Many researchers have recognized the relevance of SCM for agri-food businesses (Aramyan, 2007; Hobs and Yong, 2000; Van der Vorst, 2000) noting the perishability of the products and the need for a rigorous quality control of the products as they are passed along the chain. This can become evident when products that were quality controlled at the start of the chain deteriorate due to the carelessness of a supply chain member down the line.

The phenomenon of globalization also brought with it a considerably larger product flow, increasing the complexity of the relations between the chain members. This complexity pushed the agri-industry to create networks and new models of cooperation. Alliances were formed, vertical and horizontal cooperation proliferated, new members were added to the chain and innovation became one of the key factors driving competition. In this new world, organizations were obliged to develop and improve the quality of their products, logistics and information systems.

2.2 Performance Measurement of Agri-food Supply Chains

According to Cohen and Roussel (2004), the definition of an appropriate set of metrics allows the

performance of the activities in the supply chain to be evaluated, contributing to the diagnosis of problems and improvement in the decision making processes.

A PMS can be defined as a system that allows a company to monitor its most relevant performance indicators – related to its products, services and processes within a relevant time frame. The PMS should also be able to capture that which is essential to organizational performance and, at the same time, ensure that the metrics are being applied to the areas where their use is most appropriate. Another important factor is being able to guarantee that the organizational goals are aligned with the goals of the PMS, as such reflecting a balance between measures of a financial and non-financial nature (Beamon, 1999; Gunasekaran et al 2001; Thakkar et al 2009).

To be able to bolster the performance of the supply chain as a whole, it is necessary that the individual companies look beyond their own frontiers and are able to analyse the supply chain in its totality. Only in this way is it possible to establish a cohesive PMS, capable of accounting for the most important aspects of the supply chain, and producing information which flows along the chain.

Gunasekaran et al (2001) found that although many organizations had made significant advances in developing their supply chains, they continued to be unable to respond in an integrated way. The authors defend the idea that it is essential that the existing barrier between financial and non-financial metrics be eliminated, moving decidedly towards a more encompassing PMS which includes the two categories. While the financial measures decisively contribute to the strategic decisions, the day-to-day control of production and distribution operations is better served by non-financial metrics (Maskell, 1991).

In a later study, Gunasekaran et al (2004) classified the KPIs by management levels (strategic, tactical and operational) and grouped them in cells where the supply chain activities cross-over with the various organizational processes. The KPIs were split according to the processes (Planning, Supply, Manufacturing and Shipping), while also being ordered by decreasing level of importance. Some of them are found in more than one management level, given that their importance traverses the different hierarchical levels.

With the passage of time, PMS models have undergone changes. In the past their focus was placed on measuring costs in a short-term management perspective. Now, however, the PMS models envisage management policies for the medium- and long-term, centring on non-financial measures that make their contribution to value creation over the whole of the chain (De Toni and Tonchia, 2001).

To develop new PMS models, adaptations were made of existing management tools such as the Balanced Scorecard (Baghwat and Sharma, 2007; Chia et al 2009; Goh and Hum, 2009) or the SCOR model (Lockamy and McCormack, 2004; Hwang et al 2008). These new approaches brought new concepts and new metrics that enabled a new perspective on supply chain performance improvement, where the centre of management attention swung away from financial indicators with a short-term horizon.

However, studies focusing on the agri-food supply chain are relatively scarce. An exception is the study of Aramyan (2007), where the researcher designed a performance measurement system model focused on agri-food supply chains (Figure 1).

The researchers divided the KPIs into four main dimensions (1) efficiency, (2) flexibility, (3) responsiveness, and (4) food quality. Based on these indicators, all chain members have these four families in common, helping to assess their individual and collective performance:

- efficiency aims to measure the way in which resources are used;
- flexibility tells us the ability of the Performance Measurement System to adapt in response to changes in its surrounding environment and to extraordinary requests by the customers;
- responsiveness aims to satisfy the customer's request in the shortest time possible; and
- food quality aims to reflect the specificities of the sector at the process and product level.

Given that the framework proposed by Aramyan (2007) was evaluated in one particular context (i.e. the tomato supply chain), the author calls for the need to conduct more empirical research. The authors also mention that since performance of the supply chain is the combination of different indicators, which have different dimensions, one suitable method of analysis could be the use of composite indicators.

Computing aggregate values is a common method used for constructing indices. Indices, which can be either simple or weighted, are very useful in focusing attention and, often simplify the problem (Atkinson et al 1997). Such an approach allows for the evaluation of a multitude of aspects which can be deciphered into a single comparable index.

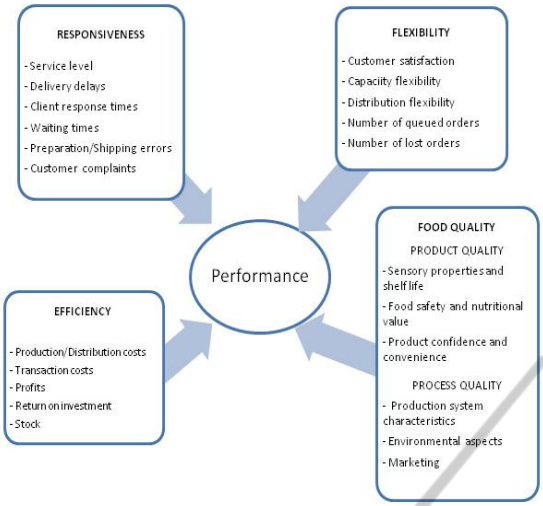

Figure 1: Aramyan's model.

3 A FRAMEWORK PROPOSAL TO ASSESS SUPPLY CHAIN PERFORMANCE OF AGRI-FOOD COMPANIES

In order to address the lack of structured systems for monitoring the performance of supply chains, the model described below was developed. The proposed model is based on the logic of the Aramyan (2007) model to evaluate the performance of the agri-food supply supply chain.

The model is displayed in Figure 2. The steps that make up the proposed model are: 1) Study of the supply chain process; 2) Identification of the dimensions and their associated indicators for monitoring; 3) Data collection and processing; 4) Compute the weights for each dimension using the AHP technique; 5) Normalize the indicators; 6) Compute the supply chain performance index.

There now follows a description of the different steps suggested for the model.

Step 1 - Modeling the supply chain.
The project must start with the study of the supply chain in order to understand its flows, stakeholders and particularities.

Step 2 - Identification of dimensions and their associated indicators for monitoring.
The chosen indicators should be appropriate to each organization and should be related to the strategic objectives of the organization. Erol et al (2011) argues that the indicators should follow three criteria: measurability, data availability and the indicators should be related to the supply chain type. In this research a set of 24 indicators were selected. Those indicators were adopted from Aramyan's (2007) model and were validated by a panel of experts from the sector.

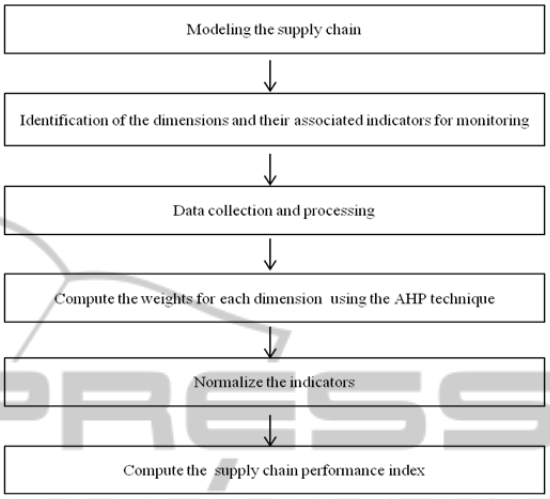

Figure 2: Model for measuring the performance of the agri-food supply chains.

Step 3 – Data collection and processing.
The instrument used for collecting the necessary data for enabling the model is a questionnaire to be sent to all first-tier suppliers and clients. This mailing, which will be done annually, allows the analysis of the evolution of the indicators to be monitored and compared with previous years. This option represents a simple and effective way to collect the information necessary to evaluate the performance of the supply chain to the extent that it is incorporated into the standard procedures that is presently implemented for supplier evaluation in most of the companies.

Step 4 – Compute the weights for each dimension using the AHP technique.
AHP, was originally introduced by Saaty (1980), is a helpful tool for dealing with complex decision making, and helps to set priorities and make the best decision possible. By reducing complex decisions to a set of pair-wise comparisons, and then synthesizing the results, the AHP helps to capture both objective and subjective aspects of a decision.

Therefore, AHP contributes to the rationalization of the entire decision process and comparatively with other multi-criteria evaluation methods (electre, ANP, promethee, etc., or even hybrid methods) is of simpler application. A good literature review can be found in the work of Subramanian and Ramanathan (2012).

The goal is located at Level 1. Level 2 of the hierarchy contains the five dimensions of the Aramyan's (2007) model. Level 3 of the hierarchy contains the indicators for evaluating each dimension.

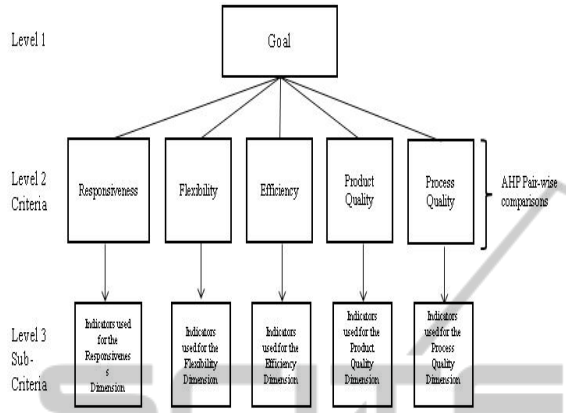

Figure 3: AHP Model for analysis of the dimensions.

An AHP hierarchy model is used to compute the weights for the five dimensions of the model. After building the hierarchy a panel of experts will be formed to assign the pair-wise comparisons to the Level 2 used in the AHP hierarchy. With this in mind, the pair-wise comparisons inherent to the AHP application will be performed as a team exercise in meetings and the final decisions will be reached by consensus. The weights of level 3 sub-criteria will not be computed using AHP pair-wise comparisons (because the possible number of pair-wise comparisons to perform would be very high). In this case we will assume that each sub-criterion will have the same weight. For example, if we have 5 indicators for one of the dimensions each will weight 20%.

Step 5 – Normalize the indicators

The main difficulty in aggregating indicators into the supply chain performance index is the fact that indicators may be expressed in different units. The following procedure will be used:

$$I^{+}_{N,ij} = \frac{I^{+}_{A,ij} - I^{+}_{min,j}}{I^{+}_{max,j} - I^{+}_{min,j}} \quad (1)$$

$$I^{-}_{N,ij} = 1 - \frac{I^{-}_{A,ij} - I^{-}_{min,j}}{I_{max,j} - I_{min,j}} \quad (2)$$

Where $I^{+}_{N,ij}$ is the normalized indicator i with positive impact from group of indicators j (Eq. 1) and $I^{-}_{N,ij}$ is is the normalized indicator i with negative impact from group of indicators j (Eq. 2). In this way, it is possible to integrate different kinds of quantities with different units of measurement. One of the advantages of the proposed normalization is the clear compatibility of different indicators, since all indicators are normalized (Krajnc and Glavic, 2005).

Step 6 – Compute the supply chain performance index

At this stage, the focus of the study was placed on the development of a methodology for measuring the performance of the supply chain. Because each indicator has different units, not comparable with each other and also have a different importance a supply chain performance index is proposed. Equation 3 calculates the supply chain performance index:

$$SC\_Perf\_Index\_sc = \sum_i \sum_j W_i \times W_{ij} \times I_{ij} \quad (3)$$

where:

- **SC_Perf_Index** - Score of the supply chain performance index
- W_i – Weight of the i^{th} dimension (calculated through the AHP judgments)
- W_{ij} - Weight of the j^{th} subcriteria of the i^{th} dimension
- I_{ij} – Normalized score for the j^{th} element of the i^{th} dimension.

The follow-up phase for the index is carried out jointly by the supply chain manager and other management departments. In the event that there are deviations from the targets established, an action plan should be put in place in accordance with the principles of the continuous improvement cycle, present in the PDCA cycle.

4 CONCLUSIONS AND OPPORTUNITIES FOR FUTURE RESEARCH

Over the last years the agri-food sector has been confronted with a wide range of challenges and demands, meaning that it has been, and will continue to be forced to provide effective responses for companies to be able to carry on business. In this context the topic of supply chain performance measurement has become a relevant subject for companies in this sector.

In this paper is proposed a framework for assessing and monitoring the supply chain performance of companies of the agri-food sector.

The framework consists of six steps to evaluate the companies supply chain performance. The linear aggregation technique is suggested to aggregate

indicators into a unique value giving rise to a composite index considering five dimensions. The proposed index results from the aggregation of indicators adapted from the model of Aramyan (2007). The proposed index proposes different weights for each of the dimensions and also for the corresponding indicators using the AHP technique with a panel formed by experts from the sector.

The proposed framework to assess supply chain performance is very friendly and easy to understand representing an important contribution to managers. Using this framework, managers can assess the impact of their strategies and management practices on their supply chain performance through the supply chain performance index value.

The practical application of the proposed framework to a case study should confirm its applicability and relevance trough the contribution to the improvement of supply chain performance of companies in the agri-food sector.

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