Development of an innovative methodology for analysis and design of supply chain networks

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Abstract
This research modifies the value chain analysis (VCA) methodology by including elements that extend its application to the analysis of supply chain networks. The VCA approach is tested on a value chain network design problem in the dairy sector. Case study and action research are used in developing the methodology.

Keywords: supply chain network analysis, dairy supply chain, methodology

Introduction

Value chain analysis (VCA) is a structured methodology for identifying the value-adding and non-value adding processes within a supply chain. VCA analyzes where in the chain costs may be reduced and differentiation enhanced (Womack and Jones 2000).

The research in value chain analysis has either focused on development of the methodology, its application to a particular setting or both. The objective of the research has been on development of methodology for the analysis of the particular steps involved in a supply chain, the wastes generated and time taken within the chain in order to make the chain lean (Rother and Shook 1998; Womack and Jones 2000). The research has in general considered the identification of the different forms of waste within the supply chain rather than the supply chain network (a supply chain view considers movement of material from the initial to the final stage in the supply chain while the supply chain network considers the network of interrelated facilities between particular supply chain echelons). In this particular study the term ‘supply chain network’ or ‘value chain network’ is meant to be the number and location of facilities within a value chain and their linkages in terms of vehicle routes.

The supply chain network design problem has been taken up as a separate area of research in the operation research domain where the objective is to develop models for optimal design solutions. Though such models may be helpful in designing new networks they do not provide a basis for analyzing existing supply chain networks. In the case under study, the dairy

processing company has to analyze the performance of its milk collection network to understand the inefficiencies and improve the network. Most often company managers do a rough analysis of the milk collection network based on their experience. However, a comprehensive methodology is required both to understand the existing network design inefficiencies in terms of cost and time, and to improve the network by capturing the intricacies inherent in real life settings.

The purpose of this research is to test the power of the value chain analysis methodology to understand supply chain networks by applying the methodology to a real life emerging market dairy supply chain. We present application of the most relevant 'state-of-the-art' value chain analysis methodology to the network analysis problem. In case where the methodology could not be completely used for analysis of supply chain network, it was modified.

Literature Review

The research in value chain analysis may be classified into two major categories: that deal with application of value chain analysis methodology to a particular setting and report findings, 2. that develop methodology for analyzing value chains. In what follows, we discuss the two streams separately.

Application of Value Chain Analysis

Zokaei and Simons (2006) use the Food Value Chain Analysis methodology using lean paradigm, value stream mapping and value chain analysis to improve consumer focus in agri-food sector. The authors present a case study of UK red meat supply chain in which they identify the misalignments in both product attributes and supply chain activities.

Francis, Simons and Bourlakis (2008) conduct a case based research employing the value chain analysis methodology to examine the beef foodservice sector. The research provides explanation and analysis of supply chain operations within the Argentine beef industry. It highlights specific supply chain waste elimination opportunities at both producer and processor level. It also establishes valuable learning points for the UK beef industry as a whole.

Singh and Sharma (2009) provide an application of value stream mapping in a manufacturing firm. VSM is the process of visually mapping the flow of information and material (known as current state map) as they are and preparing a future state map with better methods and performance based on the analysis of current state value chain map Womack and Jones (2000). Through their case study, Singh and Sharma show that value chain mapping is a useful analytical tool for making the manufacturing firms lean. Other applications of value stream mapping and analysis may be found in Brunt (2000) and Seth, Seth and Goel (2008).

Development of Value Chain Analysis Methodology

Hines and Rich (1997) develop the seven value stream mapping tools to understand the supply chain and identify supply chain wastes. The authors show the usefulness of the tools for identifying and removing the seven commonly accepted wastes in the Toyota Production System (Shingo 1989). The purpose of their paper is to help researchers and practitioners identify wastes and find an appropriate route for their reduction and possible removal in individual value chains.

The value chain analysis methodology has been developed and extended by other researchers since the work of Hines and Rich. Rother and Shook (1998) and Womack and Jones (2000) specifically develop the value stream mapping tool for visualizing the extended value chain in order to identify and reduce wastes in the system to make it lean.

Taylor (2005) presents application of value chain analysis and lean methodology in agri-food sector and develops a methodology to apply lean value chain analysis techniques to a food product supply chain. The objective is to improve the multi-echelon supply chain.

Publications on lean and VCA application in agri-foods sector are limited (Zokaei and Simons 2006). Very few empirical studies exist on application of lean and VCA in food industry (Zokaei and Simons 2006). Even lesser research on dairy supply chain in developing markets is available.

Value chain analysis research has focused on application and development of methods required for improving value chains in different sectors. No study using these methods has so far been carried out for the analysis of supply chain networks. Moreover, a detailed analysis of the application of the value chain analysis methodology to understand its comprehensiveness for capturing the inherent intricacies of supply chain networks is missing. We hence have a compelling case for a study that would analyze the effectiveness of existing tools and initiate development of new tools for analysis of supply chain networks.

This research contributes to value chain analysis literature by enhancing the methodology for analysis of supply chain networks. The study is specifically based on the value chain analysis methodology introduced by Taylor (2005).

Methodology

Following Taylor (2005) the methodological foundations used to conduct this research include value chain analysis, case study and action research. The milk collection network of a large dairy processor operating in Pakistan was studied. The processor, Engro Foods Limited, is one of the two large milk processing companies in Pakistan, the other one being Nestle. The milk collection network of both the processors is similar in the sense that the network consists of a large number of milk collection centers and dispatch points. Dairy farmers and other milk suppliers supply the milk to the collection centers. Milk collection vans originating from the dispatch points, pick milk from the collection centers on their route and bring this milk to the dispatch points. Dispatch points re-chill the milk and transfer them to larger capacity vehicles that then take the milk to the processing plant except that Nestle has a more dense population of collection centers owing to its long history in Pakistan as compared to Engro Foods Limited.

Modifying and testing the value chain analysis methodology

The value chain analysis methodology modified for and applied to the agriculture sector by Taylor (2005) consists of seven steps. We present a summary (see Table 1) of the critical analysis carried out for each step of the methodology presented in Taylor (2005) to determine its usefulness for analyzing supply chain networks.

The new approach developed as a result of this analysis was applied to a 'milk collection area' of a leading dairy processor in Pakistan. A milk collection area consists of milk collection centers and dispatch points. Milk collection vehicles take milk from collection centers in a particular milk collection area to the dispatch points, where the milk gets chilled and gets transferred to larger vehicles before going to the processing plant.

One milk collection area (from a total of 25 areas) was picked for analysis. The milk collection centers and the routes were analyzed using the current state map (see figure 1) and the vehicle route matrix (discussed in next paragraph). The facilities were evaluated on the basis of daily volume present (hence utilization), whether the facility was on a given route and the distance to be travelled if not on route. It was noted that if the volume to distance ratio of the facilities is calculated it could give a fair idea of the significance of including the facility on a given route. Volume distance ratio (VDR) indicated if enough volume was being collected to justify the cost of traversing the extra distance to collect this quantity of milk. Moreover, VDR of a given route also explained its efficiency as compared to other routes. So a volume to density data ratio was added on the vehicle route matrix for further analysis. VDRs were calculated for all the existing routes. Routes with low VDRs were picked for further analysis.

Vehicle route matrices (indicating the effect of adding or deleting a collection point from a given route on the route's VDR) were then developed and used along with current state map of the value chain network to determine desired changes in the network. Though the analysis revealed several facilities with low utilization and low VDR, only one facility was suggested to be closed for operation because of the need of the organizations in the milk processing business to collect maximum volume. However, several changes to vehicle routes were suggested based on the analysis. Routes analysis included, in addition to the current state map and vehicle route matrix, consideration of vehicle capacities, vehicle travel time and loading/unloading time.

A total of five routes were suggested for modification. Total annual savings from the shifting of dispatch points and development of new routes were expected to be approximately $25,000. The savings were coming from one target network and the one that was already performing better than the rest of the supply chain. Considering this it can be safely assumed that the exercise when carried out on the whole network would have significant impact on cost and time.

Table 1 – Application of VCA to Supply Chain Network Analysis Problem

S. No.	Specification of concepts	Application on Network Design Problem	Additions/deletions suggested in existing approach for VCA
1	Create understanding of the business potential of value chain analysis	The top management needs to be made fully aware of concepts, implications and potential benefits of an integrated and lean supply chain. Not only this, they should also be sold on the project. Corporate commitment is crucial for the success on any organizational project as it brings top management support and enthusiasm for the project which are critical elements for its success. As in case of any value chain analysis project, it is important that the top management of the organization where the network re-design exercise is being suggested is convinced on the benefits of the project.	This step is relevant for supply chain network design. However, collection of data for development of as-is network map would follow.

2	Develop overall supply chain structure map and select target value stream	In the traditional value chain analysis methodology the purpose of this step is to understand the scope of the processes that make the supply chain system. The task for the VCA team is then to draw the current state supply chain map in order to present a clear picture of the supply chain. The next step is to select a specific value stream for initial analysis and improvement. The key is to focus on a part of the complex supply chain for targeted efforts. Once the selected value stream has been analyzed and improved other value streams from the larger complex supply chain system may be picked for further analysis. The step makes sense when solving the supply chain network design problem. An understanding of the inherent supply chain system is desired for any improvement exercise. Moreover, in addition to the selecting the target value stream selecting the target network is an important element of the network analysis exercise. Even within the value stream the supply chain network would usually be made of a complex web of several facilities dispersed over a large geographical region. It therefore becomes important to pick a target network to focus the analysis effort on. Once the target network is analyzed and improved, other networks may be considered for supply chain network design (re-design) exercise.	Add the 'selection of target network' step.

3	Mapping of individual facilities along the chain	Since we are considering the whole network and the objective is to find the best operating network structure mapping of individual facilities does not remain relevant in case of designing the supply chain network.	This step to be omitted in the new approach. However, some data on individual facilities should be collected for analysis of the network.
4	Develop the whole chain current state map	The current state map is needed in the network design exercise. However, the current state map would outline the existing condition of the supply chain network rather than that of supply chain processes as in the case of VCA exercise. A detailed map of the current structure showing the location of facilities with respect to each other, existing vehicle routes and associated costs is required for an in-depth analysis of the target supply chain network.	The current state map for the supply chain network needs to be drawn. This map would primarily be showing location of facilities with respect to each other rather and existing vehicle routes rather than the holistic view of the whole supply chain. Moreover, the current state map needs to be validated with people working in within the existing network structure.
5	Identify whole chain issues and opportunities	Once the current state network structure map is ready, the next logical step is analysis of the map to identify issues and opportunities. However as in the previous stage, identification of issues and opportunities would take a different approach as in the network structure we are not merely concerned with flow within the supply chain but with configuration of the network, travel distances and time.	The issues and opportunities need to be discussed with the existing network team to ensure practical implementation aspects are taken care of before final draft of to-be map.

6	Develop the whole chain Future State Map & recommendations	Rather than drawing the whole chain map, this stage entails drawing future network map based on understanding developed from the analysis of as-is location structure and vehicle routes.	The future state map needs to be validated within the organization.
7	Creating a receptive organizational context	As for the VCA exercise, the future state map along with improvement recommendations need to be shared with the organization's top management team and agreement reached on 1. whether or not to proceed with joint improvement initiatives and 2. how the savings in cost or otherwise would be shared if there is a willingness for going ahead with the implementation of the future state map of the network.	A 'deployment of the to-be map' step to be added after this step.

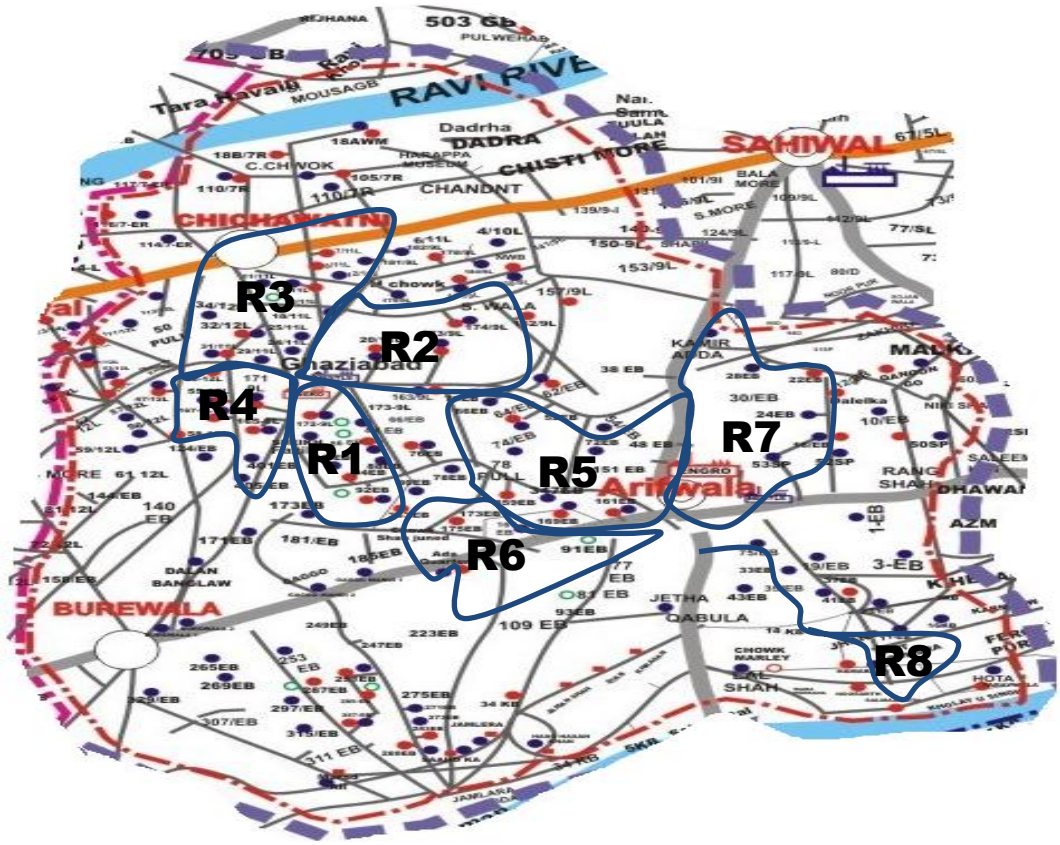

Figure 1 – Current State Map (R1- R8 indicate existing routes)

Conclusion and future research directions

In this study value chain analysis methodology was modified to analyze supply chain networks. The methodology presented by Taylor (2005) was taken as the benchmark because it was closest to the situation under study (the paper presents a case of VCA application in the agri-food sector) and most recent as well. However, as the value chain analysis methodology and its associated tools were applied to understand the milk collection network and prepare the new structure map, it was realized that a new methodology and tools are required for analyzing and re-engineering the supply chain network. Though the new methodology does not differ from the value chain analysis methodology in concept, the focus is different and hence the requirement for analysis and tools.

The study showed that value chain analysis methodology could not be applied in its current form to analyze a supply chain network. The methodology was modified to cater to the specific requirements of analyzing a supply chain network. The revised methodology was tested on a real life milk collection network in a developing economy and was found to be useful in analyzing the network. The methodology is fairly easy to use and provides a convenient tool for managers to design cost efficient supply chain networks.

Future research may focus on testing the application of this methodology on other cases. Though the methodology is expected to be robust in its application to other network analysis problems, a test exercise would provide a strong case for believing this.

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