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Exploring the greening of the food supply chain with lean thinking techniques

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Abstract

In this paper, a systematic approach for determining the waste in the agrifood supply chains is presented and analyzed. The suggested approach will be based on Lean thinking techniques so as to identify sources of waste in the targeted supply chain. Specifically, the Value-Stream Mapping (VSM) tool is proposed for determining waste, in terms of measuring the carbon dioxide emissions particularly across organizational boundaries. Authors argue that lean thinking techniques can be considered as effective tools for identifying the factors that influence the total emissions in the targeted supply chain and also for decreasing waste as measured by carbon dioxide emissions.

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Keywords: Food Supply Chain; Lean thinking; Green Supply Chain; Value Stream Mapping; Carbon dioxide emissions

1. Introduction

A typical agrifood supply chain is considered as a complex network that consists of a number of entities linked from 'farm to fork', such as farmers, input suppliers, cooperatives, packhouses, transporters, exporters, importers, wholesalers, retailers, and finally consumers [1]. The structure of the agrifood industry may be really complex and for some products, it is quite extended including many entities and resulting in numerous interactions. On the other hand supply chain is an area for competitiveness in agrifood sector because it plays a vital role in an organization's efforts to align its processes to its partners both up and downstream and most importantly to its customers. Chopra and Meindl (2007) discussed that "*each stage in the supply chain is connected through the flow of products,*

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information, and funds. These flows often occur in both directions and may be managed by one of the stages or an intermediary" [2].

On this basis it could arguably be stated that as the physical products moved from upstream to downstream it acquired some level of value as much as it incurred some cost. Both these were passed on to the customers. The more cost it incurred, the more expensive it would be for the customer and the lesser the supply chain surplus would be. This could be competitively detrimental to a profit oriented or grant dependant supply chain.

To respond to this challenge would require deploying an operations approach that would help minimize operating costs while enhancing the quality of the end product. As a starting point, it was important to understand that operations approaches aimed at providing a way through which the organization's resources in terms of human, financial and even machinery were well matched with the market requirements. Therefore, the application of a specific operations approach would be as critical as the choice itself. Slack and Lewis (2003) presented five approaches to operations as including the following: 1. Total Quality Management, 2. Lean thinking , 3. Business Process Reengineering, 4. Enterprise Resource Planning, and 5. Six Sigma [3].

Lean thinking is one such approach that had gained significant popularity over the years due to its ability to identify and eliminate non value adding but cost incurring activities. The approach had recorded significant successes resulting in a worldwide and across sectors recognition including products and services. The success of this operations approach was supported firmly by Womack and Jones (1996) through their illustration using a number of companies (case studies and best practices) that had deployed the approach and experienced the benefits in a significant way [4]. In their work the authors provided detailed analysis of how companies deployed lean principles to prevent the near collapse of the company. The conclusion drawn, however, was that five lean principles ought to be implemented for benefits to be realized. These included: 1. Definition of value from a customer's perspective, 2. Identification of the entire value stream and eliminating waste, 3. Creation of the value stream, 4. Production in response to customer demand, and 5. Pursuit of perfection.

Overall, Lean thinking was based on principles, techniques and tools all aimed at ensuring quality customer service as perceived by the customers themselves. Valuable processes, therefore, ought to be in place in order to realize this. However, it was common knowledge that every operation would potentially have a mixture of processes that would be value adding and non value adding. Non-value adding processes were characterized by wastes of different forms. These were classified as the seven wastes of a business process and included the following: Overproduction, Waiting, Transportation, Processing, Inventories: raw material, work-in-process, and finished goods, Moving: both operator and machine, and Defects: defective products or process outputs [5]. The understanding of these classic wastes was important as they formed part of the prerequisites for deploying value streaming in a more successful and effective manner. Further, central to the successful implementation of lean operations by companies was streaming of all processes that would be responsive to a customer's perception of value and eliminating the rest that incurred costs without any corresponding returns in investment. Second, only to customer's perception of value, value streaming formed a foundation on which other principles, listed earlier, could be implemented. The choice of the tools for value streaming should be appropriate and right first time. Hines and Rich (1997) suggested seven value stream mapping tools including the following: 1. Process activity mapping, 2. Supply chain response matrix, 3. Production variety funnel, 4. Quality filter mapping, 5. Demand amplification mapping, and 6. Decision point analysis and physical structure [6]. The appropriateness of each of these tools in the elimination of the seven wastes varied from tool to tool and was categorized as high, medium and low. The authors further argued that the choice of which tool to use should be determined through the involvement of the key managers of the processes in the value stream under consideration.

Most of the tools used in Lean thinking aim to change a company in order to adapt it to the customer's need. Some of the techniques used are: Takt Time, Kaizen, Statistical Process Control, Poka-Yoke, 5S, Value Stream Mapping (VSM), Total Quality Management, Kanban, and Jidoka, among many others. Plenert (2007) emphasizes the significance and usefulness of the VSM as a key tool of Lean thinking [7]. A VSM helps on identifying opportunities for Lean improvement by spotting activities dad did not add value to the process. VSM is a visual representation of processes within a pathway and can be considered as a visual map of all the activities, illustrating how they linked to each other, and information such as timing and resources. It aims identifying all the value-add and non-value-add (waste) activities, as an opportunity to remove non-value-add steps and eliminate waste through problem solving, to standardize and improve value-added processes but mainly to eliminate waste. It had four stages, beginning with preparation, current map, future map, and finally, an improvement plan.

The main objective of this paper is to propose a systematic approach for measuring the environmental performance of supply chains in food sector based on Lean thinking techniques so as to identify sources of waste in the selected supply chain. Specifically, Value-Stream Mapping (VSM) is suggested for determining waste, in terms of measuring the carbon dioxide emissions particularly across organizational boundaries. The suggested approach includes specific steps and tasks which are presented and analysed.

This study is a one of the deliverables of a national research project under the Research Project Thales titled “Implementation of green development in agrifood supply chains”. It is a three-year project that was launched in April 2012, running until April 2015. This project will design implementation models and a respective “green” performance measurement toolset for assessing environmental sustainability of agrifood products on a supply chain level. The models and toolset will be tailored to the following supply chains of the agrifood sector; peach, tomato and corn supply chains. An in depth analysis of the above agrifood supply chains will be conducted. The analysis includes a value chain analysis taking into consideration economic, technological and environmental criteria for grouping different activities and sub-activities of the selected supply chains.

Value chain analysis will allow the identification of the various sources of waste in the selected supply chains. A suggested technique to be implemented in this phase is the Value-Stream Mapping (VSM), which is a widely deployed management technique for determining waste, particularly across organisational boundaries. This technique can be applied by individual companies initially but also extend it to the supply chain. The main objective aims to assess the current status of the selected agrifood supply chains, in the context of environmental sustainability (green) practices implemented in retailing, distribution, processing and primary production, focusing on SMEs, so as to improve significantly the understanding of the examined supply chains, to identify areas of potential improvement and to establish a data collection methodology for current sustainability status assessment.

The rest of the paper is organized as follows; Section two presents and analyses the existed literature review regarding the application of lean thinking and especially the VSM tool techniques for an efficient and effective waste management. Section three presents the proposed systematic approach for measuring the environmental performance of supply chains. Finally, at the Conclusions part, the expected benefits as well as the challenges are discussed and the scope of further research is provided.

2. Applying green and lean thinking practices in the agrifood sector

Although environmental sustainability assessments have traditionally focused on agriculture [8, 9], recently researchers and policy makers have made attempts to develop more holistic approaches by incorporating stages of food processing, transportation and food retailing in the assessment frameworks of food supply chains [10, 11].

Various approaches have been developed to measure environmental sustainability of the food supply chains that identify effects at regional, industrial, and firm levels. Some specific “green” assessment frameworks developed for the food sector include farm economic costing [12], lifecycle approach to sustainability impacts [13, 10], food miles ([14], energy accounting in product lifecycle [15], mass balance of food sectors [16], ecological footprint [17], and farm sustainability indicators [18].

There are also many researches that concentrated to the application of Lean thinking for greening the supply chains. As Womack and Jones (1996) wrote: “*Lean thinking must be “green” because it reduces the amount of energy and wasted by-products required to produce a given product*” [4]. Simpson and Power, (2005) investigate the relationship between supply relationship, lean manufacturing, and environmental management practices proposing a conceptual framework to depict this relationship [19]. Yang et al. (2010) also explored the relationships between lean manufacturing practices, environmental management, and business performance outcomes [20].

Mollenkopf et al. (2010) examine the relationship among green, lean, and global supply chain strategies as found in the literature, while Mason, Nieuwenhuis and Simons (2008) try giving answer to the following question: “*How strong is the link between being Lean and being Green?*” [21, 22]. They also take one business process improvement technique incorporated within the Lean Thinking paradigm -Value Stream Mapping- and attempt to adapt this method to the requirements of industrial ecology. Overall, the application of Lean thinking techniques for Greening the supply chain has been also the objective of many researches. The following table summarizes the research initiatives that deal with the application of the Lean thinking techniques and practices for waste identification.

Table 1. Applying lean thinking techniques and practices for waste identification.

Author(s) / Publication year	Title	Research objective(s)
Venkat and Wakeland / 2006 [23]	Is Lean Necessarily Green?	Investigation of the environmental performance of lean supply chains using carbon dioxide emissions as the key performance indicator
Simons and Mason / 2002 [24]	Environmental and Transport Supply Chain Evaluation with Sustainable Value Stream Mapping	Examination of the emission characteristics of a generic food supply chain which includes both transportation and cold storage
Cox and Chicksand / 2005 [25]	The limits of Lean Management Thinking: Multiple Retailers and Food and Farming Supply Chains	Investigation if there are limits to the application of lean management thinking in complex supply chains
Tanco et al. / 2013 [26]	Applying lean techniques to nougat fabrication: a seasonal case study	Discussion of the applicability of lean manufacturing's body of knowledge to a different environment: a seasonal food industry

All the above studies justify what Florida (1996), King and Lenox (2001), and Rothenberg et al. (2001) argue that "*when using lean principles to achieve environmental production, it will bring also considerable cost benefits besides green production since Lean thinking has common goals with environmental production*" [27, 28, 29].

In the recent years a number of researches have focused on the application of Value Stream Mapping for supporting the greening efforts. A great work has been done by the United States Environmental Protection Agency (USEPA) when at 2007 first introduced the Environmental Value Stream Mapping (EVSM) method, which has all the characteristics of its parent -Value Stream Mapping- but additionally environmental issues and the usage of material or energy. Another organization in US; the USA Environmental Protection Agency (or EPA), at 2007 proposed the Energy Value Stream Mapping (EnVsm) as a tool which has the information and data about energy usage of each process item as well as its regular lean data in the typical format (VSM). The aim of the above tool is to have both data from the value added action and process beside the energy usage or waste in a same picture so to give this opportunity to the analyzer team to improve the future state of the process in a way that has better and more efficiency in both ways; lean principle and energy saving [30].

Authors of this study also argue that the above tools / methods can be used by the logistics and supply chain managers who can take advantage of them to identify and reduce the waste in a supply chain. It can also be useful for other researchers to make them more "green". Based on the above studies and initiatives this paper explores the application of the VSM tool in the typical format so as to determine the waste in the agrifood supply chain.

3. Designing a systematic approach for determining the waste in the agrifood supply chains

The main objective of this paper is to propose a systematic approach for determining the waste in the agrifood supply chain. The suggested approach will be based on a key Lean thinking technique the Value-Stream Mapping (VSM). The approach consists of specific steps as it is depicted in the Fig. 1.

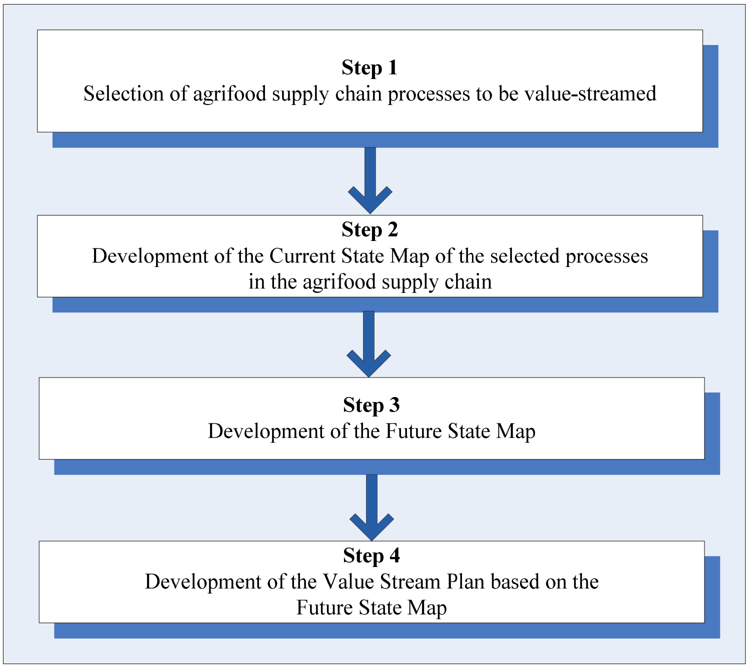

Fig. 1. An approach for Value-Stream Mapping (VSM) deployment for determining waste in the agrifood supply chain.

Step 1: Selection of agrifood supply chain processes to be value-streamed. This step includes the selection of particular processes that would be studied in depth in the next steps. In order to identify these processes in the examined sector a number of criteria can be applied. After synthesizing the literature [31, 32, 33, 34, 35, 36] the following criteria have emerged:

- Processes that require significant amounts of inputs / resources, such as pounds of materials used, pounds of hazardous materials used, gallons of water used, gallons of water consumed, watts of energy used, etc. These inputs can be also examined for every stage of the agrifood supply chain [37]; from production: water, chemicals (fertilizers, pesticides, etc.), seeds, diesel (from tractors, mechanical harvesters, etc.), etc., then, to primary processing: water (for washing, etc.), chemicals (pesticides, etc.), packaging (glass, etc.), diesel, electricity, etc. Also, to secondary processing such as gas, water (for washing, etc.), chemicals (food additives, etc.), packaging (glass, etc.), diesel, electricity, etc. Then to retail: water, gas, packaging (plastic bags, etc.), etc., and finally, to household: electricity, water, gas, diesel, packaging (plastic bags, etc.), etc.
- Processes that emit significant amounts of outputs, such as pounds of solid waste generated, pounds of hazardous waste generated, pounds of air pollution emitted, etc. These outputs can be examined for every stage of the agrifood supply chain [37]; from production: releases to water (nitrogen, etc.), emissions to air (carbon emissions, etc.), solid waste, etc. to, primary processing: releases to water (chlorine, etc.), emissions to air (carbon emissions, etc.), solid waste, packaging, etc., then to secondary processing: releases to water (chlorine, etc.), emissions to air (carbon emissions, etc.), organic solid waste, packaging, etc. Finally, to retail: releases to water (chlorine, etc.), emissions to air (carbon emissions, etc.), organic solid waste, packaging, etc. and to the household: releases to water (chlorine, etc.), emissions to air (carbon emissions, etc.), organic solid waste, packaging (plastic bags, etc.), etc.
- Processes that regularly generate problems, errors and delays regarding the environmental impacts and/or refer to the disorganized area, and
- Finally, processes that have significant impact to customers or are most visible to customers in terms also of their environmental impacts.

In the www.greensuppliers.gov an indicative list of common processes in the agrifood sector can be found including: metal fabrication (milling, welding, stamping, and machining), parts washing, surface cleaning, plastic forming (extrusion and molding), metal finishing, surface coating, chemical formulation, hazardous materials handling, waste management, and wastewater treatment [38].

Both the proposed criteria and the indicative list of processes can be used for the construction of the Process Activity Mapping matrix tool. This is a simple matrix which constitutes the processes' steps the company performed and the services that the company provides. Using this approach a particular service can be linked with an applicable process by way of placing a specific indicator in the corresponding box. This indicator actually reveals the significance of one process regarding the investigation of the environmental impact. Reader can find an example of the deployment of the tool in a real case (pharmaceutical sector) in Folinas and Ngosa (2013) work [39].

Step 2: Development of the Current State Map (CSM) of the selected logistics processes in the agrifood supply chain. This map depicts diagrammatically how the selected processes (value stream) performed at the time. Therefore, it can be considered as a snapshot of the current practices and materials usage rates for these processes. Additionally, this map aims to collect and record information where environmental impacts occur in the agrifood product line. Through this step both qualitative and quantitative pieces of data can be collected for the identification of waste. The data are categorized into two groups:

1. General information including the following issues: cycle time, change over time and up time, processing time for each of the logistics tasks performed, reliability of equipment used and availability of such materials as packaging, the number of hours elapsed between the time an assembled order was delivered for checking and packing to the time it was marshaled into dispatch area, the duration an order would stay in the dispatch area before it was loaded on a truck for deliveries, average waiting time for each order, number of operators, etc.
2. Specific information, which according to www.greensuppliers.gov (n.d.) include the following: pounds of materials used, pounds of hazardous materials used, gallons of water used, gallons of water consumed, watts of energy used (watt-hour per pound of output), BTUS of energy used, pounds of solid waste generated, pounds of hazardous waste generated, pounds of air pollution emitted and gallons of wastewater treated.

The aim of this process is to have both data from the value added action and process beside the energy usage or waste in a same picture to give this opportunity to the analyzer team to improve the future state of the process in a way that has better and more efficiency in both ways; lean principle and energy saving [30].

Step 3: Development of the Future State Map. The Future State Map symbolized the starting point for the improvement activities. Therefore, specific questions can be used for the identification of improvements:

- What is the energy consumption (electricity, etc.) of each machine, conveyer or any other tools during the running of the processes? Moreover, what is the energy consumption during the logistics activities (such as transportation, distribution or inventory?). For example, inventory in the process can consume energy for heating or cooling and transportation between stations with lift truck or crane is such big energy consumption in an agrifood manufacturer. Overall, the main objective is to assess the amount of energy used for each task in the examined processes. Moreover, to identify the non-value added processes (such as unnecessary transport); so by eliminating the non-value added processes the corresponding energy which has used can also be considered as value added or non value added energy.
- How often are orders marshaled for the production of an agrifood product? This question is related to the demand for this product and aims at understanding the workload in relation to available time i.e. takt. Moreover, what are the constraints in the above operations? Anything that was higher than the takt time can be considered as a potential constraint. These questions can be related with the following question: Is there significant queue time at the various stages of the supply chain? The value of this question is to prompt the managers to consider ways of minimizing or completely eliminating queue time not only overproduction and excess inventory of the agrifood products.
- What other improvement are required regarding the environmental impacts? The improvements can be made by changing the processes' tasks in a way that they use less energy or even to remove those activities

by using other production and/or logistics approaches and methods in lean system or even changing the technology which is used in these processes.

There are some example cases of the development of Current and Future State Maps in the literature. Reader can check the following studies for more details [40, 41, 42, 43, 44, 45, 46].

Step 4: Development of the Value Stream Plan (VSP) based on the Future State Map. This step involved the design or drafting of the plan based on the Future State Map. The VSP includes the following information:

- Information regarding the project of the application of the suggested improvements, such as the title and description of the project, its goals and objectives, the responsible process managers / supervisors and the timeframe / scheduling.
- Information regarding the examined logistics processes, such as the title, description, status (not started, in progress, completed), impact, and priority.

Each of the improvement activities aimed at either eliminating non value adding steps in order to reduce on the length of the value stream which subsequently would contribute to the reduction of the total process, lead and customer query cycle times and consequently the energy consumption and emissions.

4. Conclusions

This paper provides a perspective of the application of the Lean thinking tools to support the green supply chain and logistics management initiatives. After synthesizing the literature a step-by-step approach for determining the waste in the agrifood supply chain is proposed. The suggested approach proposes the Value Stream Mapping, which is a basic Lean thinking tool. Authors argue that the VSM analysis can be an effective and efficient tool for a number of improvements not only for the identification of the wastes but for the determination of the greening of the agrifood supply chain.

There are also many challenges that need to be considered for future study regarding the examined sector. First, in the examined sector lean strategies require just-in-time delivery of small lot sizes which in turn leads to an increased transportation, packaging, and handling activities that may oppose a green approach. Moreover, especially during the economic downhill companies in the agrifood sector and in countries like Greece seek to increase their export efforts. Introducing global supply chain management into the green and lean equation increases the potential conflict between the green and lean initiatives." So as companies begin to implement lean and green strategies in supply chains, especially large and complex global supply chains, manufacturers need to explore the overlaps and synergies between quality-based lean and environmentally based 'green' initiatives, and understand the various trade-offs required to balance possible points of conflict. Finally, there is a need to evaluate and possibly improve this tool, based on practice and the applicability in the examined.

Therefore, considering the above challenges future research includes the application of the proposed approach for determining waste, in terms of measuring the carbon dioxide emissions particularly across organizational boundaries in specific supply chains (corn, tomato and peach) in order to demonstrate its applicability and effectiveness.

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