# APPLYING LEAN THINKING TECHNIQUES IN THE AGRIFOOD SUPPLY CHAIN

**Dimitrios Folinas***
Department of Logistics, Technological Educational Institute of Central Macedonia,
Kanellopoulou 2, 60100, Greece, dfolinas@gmail.com
**Dimitrios Aidonis**
Department of Logistics, Technological Educational Institute of Central Macedonia,
Kanellopoulou 2, 60100, Greece, daidonis77@gmail.com
**Nikos Voulgarakis**
Department of Logistics, Technological Educational Institute of Central Macedonia,
Kanellopoulou 2, 60100, Greece, voulgarakis.nikos@gmail.com
**Dimitrios Triantafylou**
Department of Logistics, Technological Educational Institute of Central Macedonia,
Kanellopoulou 2, 60100, Greece, triantafilloudimitrios@yahoo.gr

***Abstract***: *In this paper, a three-step approach for measuring the environmental performance of specific supply chains in agrifood sector based on the Value-Stream Mapping (VSM) technique is proposed and analyzed. The approach aims to determine waste, in terms of measuring the non value-added time of production and logistics processes, as well as, water and energy used across organizational boundaries. Furthermore, in order to demonstrate its applicability and effectiveness and to understand its sustainable impacts, the suggested approach is applied in an agrifood product (corn) and the corresponding supply chain. VSM diagrams are created and specific practices are proposed in order to minimize waste in the examined supply chain.*

***Keywords:*** *Food Supply Chain, Corn for animal feed, Lean thinking, Green Supply Chain, Value Stream Mapping.*

* Corresponding author

## 1. INTRODUCTION AND LITERATURE REVIEW

Lean thinking is an approach that has gained significant popularity over the last years due to its ability to identify and eliminate non-value adding but cost incurring activities. The approach has recorded significant successes resulting in a worldwide and across sectors recognition including both products and services.

The success of this 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 [18]. In their work the authors provided detailed analysis of how companies deployed lean principles to prevent the near collapse of a 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 can be defined as a set of principles, techniques and tools all aimed at minimizing non-value adding processes which are characterized by wastes of different forms. According to Emiliani and Stec (2004) 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], [6], [8].

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) and Abdulmalek and Rajgopal (2007), emphasizes especially the significance and usefulness of the VSM as a key tool of Lean thinking [10], [1]. A VSM helps on identifying opportunities for lean improvement by spotting activities that are 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 has four stages, beginning with preparation, current map, future map, and finally, an improvement plan.

On the other hand, there are business sectors and their corresponding supply chain networks that the application of Lean thinking techniques seems to be very promising. In this paper, the study is focused on the agrifood sector. This sector is characterized by real constraints on natural resources, as well as, high production costs, higher risks, and competition for resources by the producers [2], [3], [11]. There is a high need for decreasing the lead time due to the nature of the products and this decrease could easily translate to lower financial costs and lower inventory management cost. Moreover, there is also the "consumers' awareness need" who (customers) are better informed and better educated in terms food quality, food safety and food nutrition issues.

In the literature there are many researches that concentrated to the application of Lean thinking for greening the supply chains [4], [13], [15], [17]. 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*" [18]. Simpson and Power, (2005) investigate the relationship between supply relationship, lean manufacturing, and environmental management practices proposing a conceptual framework to depict this relationship [14]. Yang et al. (2010) also explored the relationships between lean manufacturing practices, environmental management, and business performance outcomes [19]. 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" [7], [9], [12].

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 [6].

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 a specific agrifood supply chain of the corn product for animal food. Therefore, 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, VSM is suggested for determining waste, in terms of measuring the water, energy and lead time of the production process.

## 2. CASE STUDY

In this section the Value Stream Mapping (VSM) tool is used in order to develop a visual representation of existing operations (Current State Map, CSM), so as to identify the largest sources of waste (non-value added activity) in the value stream of the corn supply chain and especially the production process of animal food products, as well as, to develop an implementation plan for lean techniques (Future State Map, FSM). The examined company is one of the biggest feed companies in Northern Greece. It produces compound feeds for poultry, rabbits, cattle, sheep & goat, pigs, horses, pets, etc. Two interviews were arranged with the Production Manager and Operations Manager in order to apply in practice the following three-step approach.

Step 1: Selection of agrifood supply chain processes to be value-streamed. A typical production process after the harvest of the corn and its supply either from the national or global market is executed as follows. Corn comes either from farmers or suppliers (both in domestic or foreign market). First, corn drying is a necessary post-harvest process that prevents the growth of microorganisms and deterioration of the product (for prolonged storage, a moisture content of less than 14% is recommended). The energy consumption for corn drying varies due to the variability in corn's moisture content, which usually ranges from 16-22%. The required energy to reduce moisture content of corn from an initial value of 22% to the desired 14% is estimated to be around 520 BTU/t [16]. Due to the short harvesting period, industries that produce animal feeds on a large commercial scale are forced to store large amounts of dried corn in specifically designed silos with a capacity of a few thousand tons (usually around 2000 tons). In order to preserve quality, it is necessary to aerate frequently the silos with high power electric blowers. The feed mills are also forced to transfer previously stored cereals from one silo to another, which aims at preventing temperature rise. It is difficult to predict the energy requirements for such processes because these depend on both storage time and corn quality. Besides the aforementioned preservation methods, common practice is the addition of preservatives (e.g. ammonium propionate) at concentrations of 2-3‰. Due to the limited financial fluidity, feed mills do not proceed to the storage of large amounts of corn during the harvesting season; rather they procure the necessary amounts from either domestic wholesale or directly via imports.

The production of animal feed mixture follows. Well-organized feed mills produce various types of animal feeds for feeding all kinds of livestock. The amount of corn added to the different types of animal feeds varies between 10-70%. For the production of a typical mixture of animal feed for chicken fattening (broilers-final stage), the amount of corn added is up to 60%. In this mixture, various proteinaceous ingredients are added (soy bean meal, fish meal), lipids, inorganic nutrients (calcium, phosphorus, magnesium, salt, minerals) as well as a multi-vitamin mix.

The production process includes the following stages: weighing, grinding, mixing, pelletizing, and packaging in bags or bulk transportation to the fattening units with silo vehicles. Energy consumption for the production of palletized animal feeds is at an average 85kWh/ton (according to the Advisory Committee on Animal Feeding stuffs - ACAF/ 53rd Meeting on 2 March 2011). Water consumption, in the form of steam, during the production process ranges from 40-60 kg/ton of product. According to these values, the energy consumption for corn solely, as part of a chicken feed mixture is 85 kWh x 60% = 51 kWh/ton final product. The respective amount of water accounts for 24 to 36 kg/ton of final product. Gas emissions to the environment are limited to the amounts necessary for the combustion of gas/oil for the production of steam, mentioned above. No liquid wastes are formed during the production of animal feeds, while solid wastes, in the form of dust, are easily held by filter bags and are not considered an environmental hazard.

In order to identify the corn supply chain processes to be value-streamed we use the following criteria: 1) processes with high energy, water, material and hazardous material use, 2) processes with significant solid or hazardous waste generation, 3) processes requiring environmental permits or reporting to environmental agencies, and 4) processes that include special pollution control equipment. Based on the proposed four criteria we asked the two managers to evaluate the significance of the processes that emerged from the production procedure in the examined case. Managers took into account the effects, causes and environmental impact of the seven wastes as depicted in Table 2 and evaluated the processes using four values: Not significant, Low, Medium and High (significance).

The following table presents and evaluates the processes that were identified with the above criteria based on the responses of the Production and Operation managers (Table 1).

**Table 1. Identifying the corn supply chain processes to be value-streamed**

| Criteria / Process | High energy, water, material and hazardous material use | Significant solid or hazardous waste generation | Environmental permits or reporting to agencies | Special pollution control equipment need |
|---|---|---|---|---|
| Drying | High | Medium | Low | Low |
| Storage | Low | Not significant | Low | Low |
| Weighing | Low | Not significant | Not significant | Not significant |
| Grinding | High | High | Low | High |
| Mixing | Medium | Low | Low | Low |
| Pelletizing | High | Low | High | High |
| Packaging | Low | Not significant | Medium | Medium |

According to the above findings all the processes were selected for the development of current and future stream maps (Step 2 and 3).

Step 2: Development of the Current State Map (CSM) of the selected logistics processes in the agrifood supply chain. In order to develop the CSM of the corn supply chain, a number of calculations were made in every process of the animal feed production that was identified in the previous step. The study was focused on the environmental aspects of the targeted procedure and was referred to liters of water and energy used as depicted in the following table.

**Table 2. Estimating water and energy used**

| | Water used (lt /tn) | Energy used (kWh / tn) |
|---|---|---|
| Drying | 50 | 0.8 |
| Storage | - | 12 |
| Weighting | - | 2 |
| Grinding | - | 12 |
| Mixing | - | 5 |
| Pelletizing | 30 | 30 |
| Packaging | - | 2 |

According to the estimations some processes that were measured have some of the environmental impacts that were presented in the Table 2 but all have time and labor inputs such as the number of employees / shifts, cycle time (c/t), operation time (o/t), set up time, scrap rate, rework rate, etc. Figure 1 presents the Current State Map. In the bottom of the map there are three lines that represent: 1) Total lead time and value added time, 2) Amount (liters) of water used (top line) and amount (liters) of water needed (bottom line) per day and per process, 3) kWh's of energy used (top line) and kWh's of energy needed (bottom line) per day and per process: for measuring energy consumption a power measuring device (the power consumption of a machine for machining a part or a batch over a particular time in 24 hours) and a data logger were used. Since the examined production process is fully automated and especially from Storage to Packaging, Total Lead Time and Valued Added Time are not considerably different. Therefore, and based to Table 2, Inventory, Transportation and motion waste, as well as, the Waiting waste are not critical. Furthermore, according to the historical data maintained by the Quality Control company's department, the Defect level (caused by scrap rate, design error, machine setup, wrong process production and quality protocol assessment) is very low (~0.5% per lot) so this waste is also not critical. In contrast, there are two processes that have significant environmental impact in terms of water and energy used: Drying and Pelletizing. Moreover, three wastes according to Table 2 (Over-production and Process), have been selected for a more detailed examination.

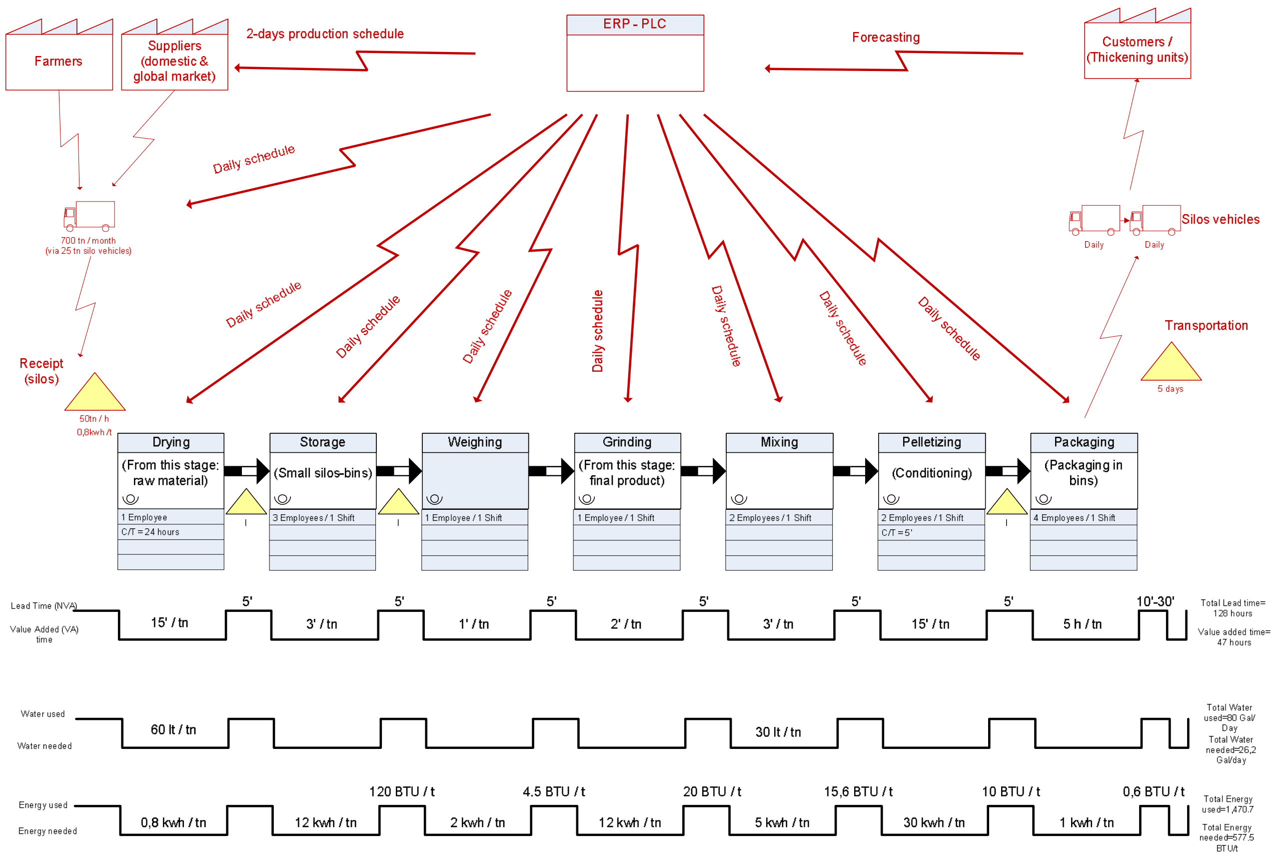


**Figure 1. Current State Map**

Step 3: Development of the Future State Map. The main objective of this step is the identification of processes with main environmental, health, and safety opportunities on the CSM. But most of all, this step includes the identification of the appropriate, practices, technologies and tools in order to minimize waste. According to the findings of the previous step, authors and the two managers of the manufacturer have focused on two wastes:

Over-production and Process, and two processes: Drying and Pelletizing.

Based on the above, three practices were proposed. First, more accurate forecasting procedures based on mathematical models and by exploiting the historical sales and production data can confront effectively with the over-production. Furthermore, the use of the takt time, based on the available working time of the downstream processes that are closest to the customer and specifically from Storage to Packaging will surely guide the production rate with the rate of sales, to meet customer requirements.

Second, animal feed production units refer to either neighboring to the plant areas and sometimes in areas that are a few hundred or even a few thousand kilometers away. As a result, the capabilities of animal feed production units for developing long-term planning strategies, regarding the supply of corn, are limited. The composition of animal feeds can be automatically formulated by specifically designed software, in order to satisfy the nutritional needs of both terrestrial animal and avian species with the least cost formulation. For instance, if the price of wheat is rising with respect to corn, then the ratio of wheat added into a product may decrease and be replaced by corn. Third, cultivation of new types of corn hybrids has gained much interest over the last few years.

These new types of corn hybrids can be naturally dried in the field (which is favored by the climate conditions in Greece), practically, without using dryers. This allows the supply of corn during the harvesting period, with an estimated moisture content of 14-15% (w/w), which is within the acceptable limits. Furthermore, it is possible to mix corn batches from different suppliers without classifying the batches into low- and high-moisture. Elapsed time for discharging 25 ton of corn in a medium-sized plant is about 30 minutes. Common practice does not require truck arrival at specific times.

Figure 2 shows the Future State Map (FSM) created for the examined production process based on the recommendations previously mentioned.

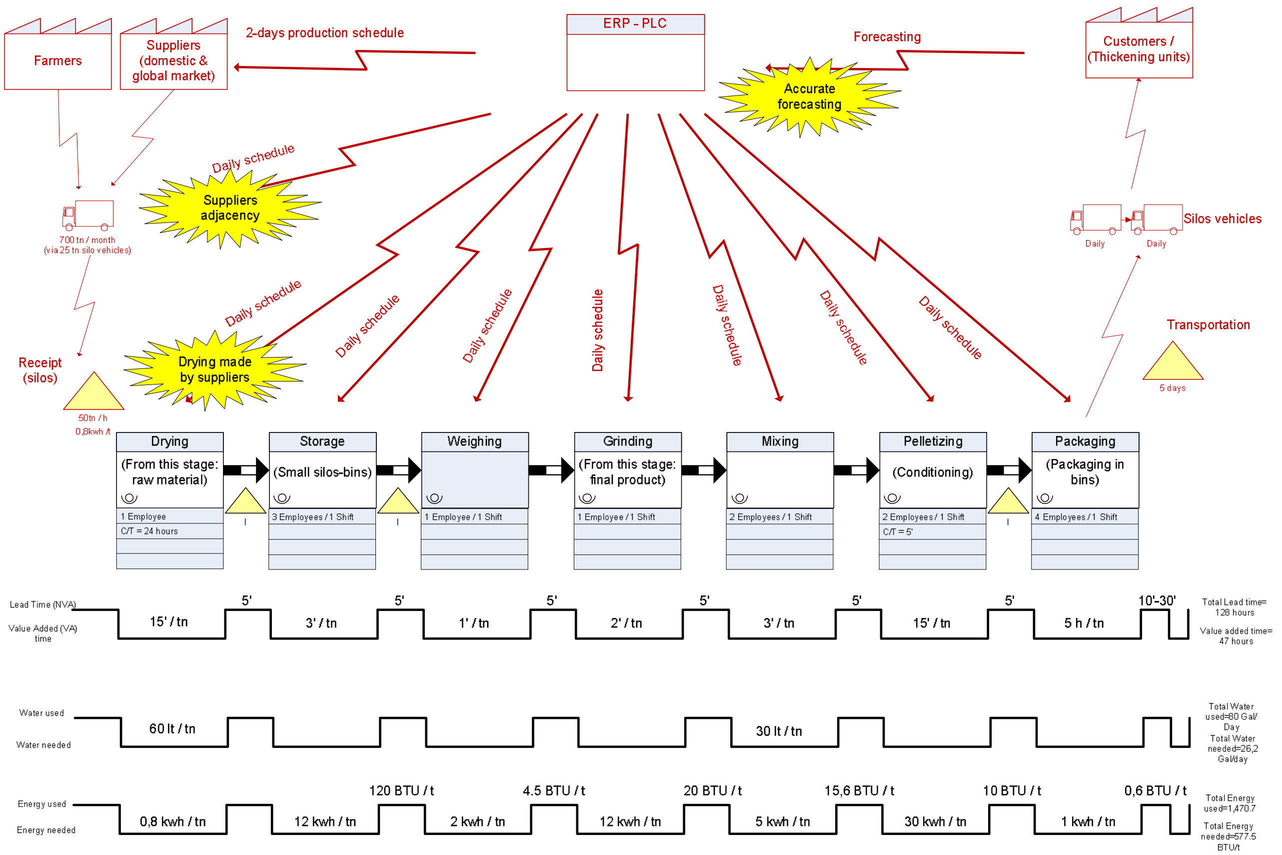


**Figure 2. Future State Map**

## 3. CONCLUSIONS

This paper provides a perspective of the application of the Lean thinking tools to support the green supply chain and logistics management initiatives. 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. The proposed systematic approach was deployed in the corn supply chain for animal feed. 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 other sectors as well.

## ACKNOWLEDGMENT

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALES. Investing in knowledge society through the European Social Fund (No. OPS 379411).

## REFERENCES

[1] Abdulmalek, F. and Rajgopal, J., 2007. "Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector", International Journal of Production Economics, 107:1:223-236.

[2] Beresford, A.K.C. and Pettit, S.J., 2004. *The development of an emergency relief logistics response model*, Proceedings of the 9th Logistics Research Network Conference, 300–310, Dublin.

[3] Chow, G., Heaver, T.D. and Henriksson, L.E., 1994. *Logistics performance: Definition and measurement.* International Journal of Physical and Distribution Management 24 (1), 17–28.

[4] Cox, A. and Chicksand, D., 2005. "The limits of Lean Management Thinking: Multiple Retailers and Food and Farming Supply Chains", European Management Journal, 23(6):648-662.

[5] Emiliani, L. and Stec, D., 2004. "Using value-stream maps to improve leadership", The Leadership and Organization Development Journal, 25:8:622-645.

[6] EPA (2007), "The Lean and Energy Toolkit. Energy", 2007;56.

[7] Florida, R., 1996. Lean and green: the move to environmentally conscious manufacturing. California Management Review, 39:1:80-105.

[8] Hines, P., Found, P., Griffith, G. and Harrison, R., 2008. Staying lean: thriving, not just surviving. Lean Enterprise Research Centre: Cardiff.

[9] King, A. and Lenox, J., 2001. "Lean and green? An empirical examination of the relationship between lean production and green", Production and Operations Management, 10:3:244-251.

[10] Plenert, G., 2007. Reinventing Lean- Introducing Lean Management into the Supply Chain. Burlington: Butterworth-Heinemann.

[11] Pretty, JN., Ball, AS., Lang, T. and Morison, IL., 2006. "Farm costs and food miles: an assessment of the full cost of the UK weekly food basket", Food Policy, 30:6:1-19.

[12] Rothenberg, S., Pil, K. and Maxwell, J., 2001. "Lean, green, and the quest for superior environmental performance", Production and Operations Management, 10:3:228-243.

[13] Simons, D. and Mason, R., 2002. Environmental and Transport Supply Chain Evaluation with Sustainable VSM, Proceedings of the 7th Logistics Research Network Conference, Birmingham, UK..

[14] Simpson, F. and Power, J., 2005. "Use the supply relationship to develop lean and green suppliers", SCM: An International Journal, 10:60-68.

[15] Tanco, M., Santos, J., Rodriguez, J. and Reich, J., 2013. The International Journal of Advanced Manufacturing Technology, Applying lean techniques to nougat fabrication: a seasonal case study.

[16] Uhrig, J. and Maier, D., 1992. Costs of Drying High-Moisture Corn. Cooperative Extension Service Purdue University.

[17] Venkat, K. and Wakeland, W., 2006. Is Lean Necessarily Green? Proceedings of the 50th Annual Meeting of the ISSS, ISSS 2006 Papers.

[18] Womack, J.P. & Jones, D.T., 1996. "Beyond Toyota: How to root out waste and pursue perfection", Harvard business review, 74(5): 140-150.

[19] Yang, C., Lin, S., Chan, Y. and Sheu, C., 2010. "Mediated effect of environmental management on manufacturing competitiveness: An empirical study", International Journal of Production Economics, 123:210-220.