Lean Six Sigma and Environmental Sustainability:

The case of a Norwegian Dairy Producer

Purpose: The purpose of this paper is to investigate the application of Lean Six Sigma in the continuous process industry, taking insight into the food processing industry; and to evaluate the impact of Lean Six Sigma on environmental sustainability. We present observations and experiences from the application of Lean Six Sigma at a Norwegian dairy producer, with the aim of bringing out pertinent factors and useful insights that help us to understand how Lean Six Sigma can contribute towards greater environmental sustainability in this industry type, something that is so far lacking in the extant literature.

Design/methodology/approach: We adopt a single, longitudinal field study approach as we observe an entire cycle of the VSM-DMAIC Lean Six Sigma process, which evolved over a six-month period at the dairy.

Findings: We highlight some of the important elements that should be considered when using LSS as a contributor towards greater environmental sustainability in fresh food supply chains. We also present some of the specific outcomes and key success criteria that became apparent to the implementation team following the deployment of the VSM-DMAIC approach.

Originality/value: We demonstrate how Lean Six Sigma can be applied in the food processing industry as a contributor to greater environmental sustainability. We also make

useful reflections regarding the success criteria that can be used by researchers and practitioners for the effective deployment of such an approach, particularly in the continuous process industry.

Introduction

Recent literature emphasizes the application of Lean manufacturing practices to food processing industries in order to improve operational efficiencies (Garza-Reyes, 2015; Dora *et al.*, 2014). Six Sigma is also identified as a key enabler of such improvement in both food producers and distributors (e.g. Knowles *et al.*, 2004; Nabhani and Shokri, 2009; Lee et al., 2013) . Though Antony (2011) suggests that the integration of the two methodologies (Lean and Six Sigma) can achieve better results than either method could achieve alone, unfortunately there has been little implementation of Lean Six Sigma (LSS) (Salah et al., 2010), especially in alternative contexts other than discrete manufacturing, particularly in the food processing industry (Kovach and Cho, 2011). This is interesting as the food processing industry represents a somewhat unconventional application area for LSS from two perspectives: firstly, the process industry has had little coverage in the extant literature when it comes to Lean and Six Sigma in general and LSS in particular (Besseris, 2011). Secondly, the food industry is of particular interest as it simultaneously attempts to deal with a number of complicating characteristics, often unheard of in other industries. For example, short shelf life of raw material and finished products (van der Vorst *et al.*, 2005; Entrup, 2007), strict hygienic regulations (Entrup, 2007), seasonality (Aramyan *et al.*, 2007), and high supply and demand uncertainty (Ivert

2

et al., 2015; Nakhla, 1995).

These challenges also make food supply chains interesting from the point of view of environmental sustainability (see for example Gerbens-Leenes et al., 2003), where Lean approaches can be an opportunity for improving process performance and reducing waste by contributing with methods for specific processes and industries (Garza-Reyes, 2015; Duarte and Cruz-Machado, 2013). Furthermore, it has been claimed that a doubling of global food demand is expected in the next 50 years. This alone poses huge challenges for the sustainability of food production (Tilman et al., 2002). As such, waste reduction in the food industry is not as simple as classification just in terms of Lean's seven wastes (Ohno, 1988), it is also important from the standpoints of raw material and energy usage, (for example Garza-Reyes, 2015; Chabada *et al.*, 2013; and Besseris, 2011). This is where the combination and integration of Lean and Six Sigma, as the two most important continuous improvement methodologies for achieving operational and service excellence, really comes in to its own (e.g. Salah et al., 2010).

This paper aims to focus on these topics by addressing the following research questions:

RQ1) *How can Lean Six Sigma be successfully applied in the food processing industry?*

RQ2) *How can Lean Six Sigma be employed to contribute towards creating greater environmental sustainability in fresh food supply chains?*

Lean strategies play an important role in the identification and subsequent elimination of waste and non-value adding activities, and Six Sigma makes user of statistical tools and techniques to lift an organization to an improved level of process performance, resource utilization and capability. In this paper, we examine the deployment of an integrated LSS approach in the food processing industry. We present specific outcomes and key success criteria from a longitudinal case study carried out at a Norwegian dairy producer in Norway.
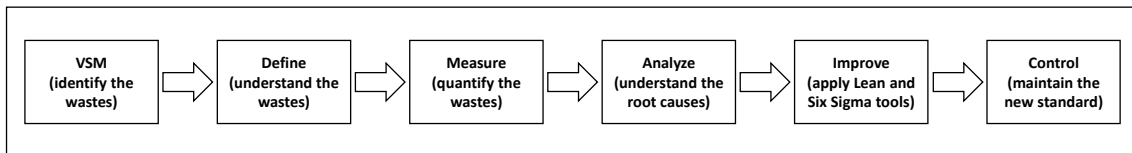
Lean Six Sigma

Lean Six Sigma (LSS) is a business improvement methodology that aims to maximise shareholder value by improving quality, speed, customer satisfaction, and costs (Laureani and Antony, 2012; Jeyaraman and Teo, 2010; Salah et al., 2010). Combining techniques and principles from both Lean and Six Sigma, it has been described as the latest generation of improvement approaches (Snee, 2010). Wheat *et al.* (2003) suggests that Six Sigma complements the Lean philosophy by providing the tools and know-how to tackle specific problems that are identified along the Lean journey, for example cause and effect diagrams, measurement system analysis (MSA), statistical process control (SPC), and design of experiments (DoE) (Besseris, 2011). A successful LSS deployment is claimed to have a significant impact on bottom-line results (Jeyaraman and Teo, 2010). For example, Snee (2004) suggests that large companies typically return 1-2 percent of sales/year whilst small to medium size companies return 3-4 percent of sales/year. These figures translate into sizeable savings. For instance, a large company with £2 billion in sales with 2 percent savings will generate a return of £40 million per year.

Lean, Green and Six Sigma: Towards greater environmental sustainability

Carvalho *et al.* (2011) suggest that green supply chain management is an important organizational philosophy to achieve corporate profit by reducing environmental risk and impact. Whilst Duarte and Cruz-Machado (2013) identify how Lean-green organizations benefit from applying specific Lean and green practices, Garza-Reyes (2015) also suggests that further integration with Six Sigma can enhance Green Lean operations. These works provide the theoretical fundament for our investigation – as we set out to identify how Lean Six Sigma can contribute to greater environmental sustainability in fresh food supply chains.

Implementation of Lean Six Sigma

Employing a standard operational framework for implementing both Lean and Six Sigma approaches is seen as an obvious and necessary step for companies to achieve benefits from both strategies (George, 2002) . Though there exist several frameworks for Lean implementation (see Powell et al., (2013) for a summary), the prevalent Six Sigma implementation framework is of course the Define-Measure-Analyse-Improve-Control cycle (Thomas *et al.*, 2008; Garza-Reyes et al., 2014; and Jirasukprasert et al., 2014). However, the choice of implementation approach for Lean Six Sigma (LSS) is vital for the success of the initiative (Jeyaraman and Teo, 2010). As such, many authors tend to differentiate LSS from "pure" Six Sigma by first introducing fundamental Lean mapping techniques such as value stream mapping (VSM) (e.g. Bendell, 2006; Engelund *et al.*, 2009; Miguélez *et al.*, 2014; Thomas *et al.*, 2008) in order to enhance the focus on increased value-added before deploying the DMAIC approach. Thus, we suggest that a LSS deployment begin first with a value stream mapping exercise to identify areas of waste (both type of waste and place of occurance), before the DMAIC cycle is deployed to understand, quantify, reduce and / or eliminate them. This is an alternative approach to that described in Salah *et al.* (2010), where the LSS model integrates VSM as part of the Measure (current state VSM) and Analyse (future state VSM) phases. Our VSM-DMAIC LSS model is outlined in Figure 1 (below):

Fig 1: *VSM-DMAIC Lean Six Sigma Approach*

Research Methodology

The aim of this empirical study is to explore the applicability of LSS in the

continuous process industry and the contribution and impact on environmental sustainability. This is achieved by analysing how the food processing industry can benefit from Lean Six Sigma in the context of reducing waste and variation in processes, focusing on value added activities and using Lean Six Sigma techniques that improve process performance and contribute to greater environmental sustainability. To support the exploratory study, the research design consisted of developing a theoretical framework that guided an in-depth case study. The theoretical framework was constructed from the Lean and Six Sigma literature where we combined the principles from value stream mapping (VSM) and the define-measure-analyse-improve-control (DMAIC) methodologies to give structure to the data collection and analysis.

The case study strategy for collecting and analyzing data was chosen since it allowed us to gain in-depth knowledge from a situation where LSS was being applied and tested in a food processing company (Eisenhardt, 1989; Yin, 2014). The case study allowed us to observe the LSS application in its natural context at the food producer and also allowed us to use the experiences and knowledge that existed in the company. When there is uncertainty in the definition of constructs (e.g. understanding the applicability of LSS in food processing industry), the case study approach will help to clarify the context (Stuart et al. 2002). Our case study took the form of a longitudinal field study, which is a special form of case-based research that provides in-depth studies of change processes as they happen inside organizations (Åhlström and Karlsson, 2009). The major difference between a longitudinal field study and a conventional case study is the issue of timing, whereby a case study is retrospective in that the researcher recollects historical events, and a longitudinal field study allows the researcher to observe the change process as it develops and unfolds in real time. The very rationale for adopting the longitudinal field study approach was to observe the real-time application of LSS in practice, thus we are

6

confident that the selected methodology delivered useful results for this investigation.

The context of the case study and the evolution of the longitudinal research was a project carried out by a team of dairy employees and lead by one of the co-authors. The project, which lasted for six-months (January-June 2013), took place at one of the dairy facilities. The activities were supported by the plant management team and was described with an aim, tasks, deliverables and a time schedule. It started with a formal project description that was confirmed by the team and plant management. Then the theoretical framework was build together with the methodology development and formulation of propositions. After a month period data where collected, analyses and discussions before the theoretical framework was adjusted, implemented and tested. The final activity was evaluation and recommendation. Data was collected according to the case study methodology using interviews, direct observations and analysis of reports, but the main data source was the researchers' participation in the implementation project where we acted as participants and change agents. One of the authors was actually employed in the company, an "insider". As an "insider", the researcher's primary role in the field study was participant observation, and group activities were used to stimulate discussions that were further used in order to reduce the risk of unintentional researcher bias that could have had a detrimental effect on the change process. By taking such a role, the quality of both the data collected as well as the results of the analysis was increased due to the inherent inside knowledge of the company.

We followed the procedures for analyzing qualitative data that are described in Miles and Huberman (1994). The field notes from the interviews were converted to detailed case descriptions. We asked the key interviewees to review the descriptions in order to ensure their validity, as suggested by Yin (2014). The transcripts were coded and analysed according to the relations in the analytical framework. Additionally, the results of the

analysis and the proposed strategies were presented and discussed in meetings and workshops with representatives from the case companies.

Case study analysis

The case company, TINE SA, is Norway's largest dairy company. Owned by 15,000 dairy farmers, Tine has over 5,600 employees and an annual turnover of approx. £2 billion (2013). The production network is complex with 34 production sites across the country and milk collected all times of the year from the supplying farmers. The yearly supply of raw milk from the farmers is approximately 1.4 billion litres of cow milk and about 19 million litres of goat's milk. Tine has five central warehouses and the distribution of its products is a combination of direct and wholesale distribution (from both the warehouses and the production facilities), with 25,000 delivery points served several times per week, including grocery stores, schools and kindergartens.

The unit of analysis of our study is one of the dairies within Tine's national network – Tine Tunga, in Trondheim, Norway. Here, the main raw material is milk, which is processed into many different product types including varieties of milk (eg. sweet- and sour milk), yoghurt, and cream products. The main criteria for selecting the company in the study were its production process attributes: The company represents the food processing industry, producing 50-60 product variants out from one main raw material. This causes many change overs which results in large amounts of waste in terms of raw material, water, energy and packaging. Additionally the company was also aspiring to implement and test LSS prior to the investigation.

We structure the remainder of the case study using the VSM-DMAIC LSS approach that was followed during the longitudinal field study.

VSM

The LSS process at Tine Tunga began with a value stream mapping exercise. However, rather than being used purely to identify non-value added activities, it was also used in this case to identify the points in the process where wastage of materials occurs. Figure 2 shows the current-state value stream map that was constructed in the initial phase of our investigation:
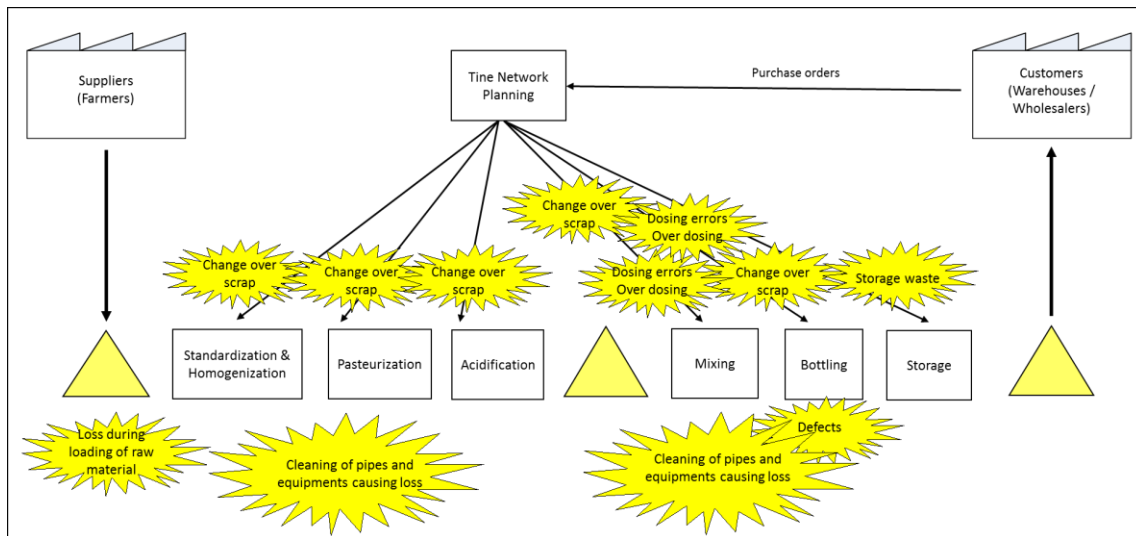
Figure 2: *Current State Value Stream Map (w. sources of waste identified)*

The VSM exercise identified that the main waste was related to the loss of raw material (mainly milk), in the start-up and in-process stages of the process – where most waste was found when shifting from one product type to another.

Define

The management team at the dairy had an initial project meeting with the researcher (project manager) to define the scope of work. The aim for the meeting was to define a project that could explore the identified sources of waste in the dairy in greater depth in order to understand and solve the challenges of waste raw material and products at the dairy. The team defined the goal of the project, which was to reduce the wastes identified

in the current-state VSM and to achieve the highest possible yield at the dairy from the available raw materials; milk, jam, sugar, powdered milk, and cereals. This project focusses primarily on milk since this is the main ingredient measured in volume and value.

Measure

In order to quantify the waste materials, Tine adopted the measure *Total yield*. Total yield is an explicitly measured KPI at Tine, recorded every month. In order to improve the yield it was necessary to gain more in depth information, such as: yield per raw material, yield per machine, yield per process step, yield per product, and loss in different waste streams (e.g. waste water, over-dosing in product, scrap / defects, etc.). It was decided that this information should be measured and reported more regularly in order to react quicker in terms of taking actions towards improvement. A spreadsheet was created to calculate yield of milk on a weekly basis. It was noted that one of the greatest challenges for the LSS project was to identify effective ways to measure.

Analyse

The analysis of the wastes identified in the current-state situation was carried out by arranging several workshops together with project team and the Lean coordinator at the dairy. The basis for this work was Pareto analyses followed by 5M (cause and effect) analysis (Ishikawa and Lu, 1985), which revealed the following:

- Total waste of milk, jam, sugar, powdered milk, and cereals were approx. £1 million (2012).

- Milk wastage in the bottling lines contributed to approximately 80% of the total cost of waste. The extent of this waste is related to how early in the value stream the different product variants are produced. The less product variants, the further

upstream in the value chain, the lesser the extent of waste which occurs.

- The amount of shrinkage is inversely proportional to batch size (due to changeover losses / start-up scrap).

Improve

In total, seven workshops were arranged during the project, where employees from different production departments participated together with the core LSS project team. The different workshops had different focusses, and the final two workshops focused on improvement initiatives. The following improvement actions were agreed upon:

- Define and implement improved measures (KPIs) for each department (Bhasin, 2008). Two to three KPIs and targets were defined for each department, and will be measured on a weekly basis. These include yield for each intermediate product (litres), yield for each bottling machine (litres), and milk loss (litres and %).

- Implement process changes and standard work (Ohno, 1988), and improve communication in order to re-use the milk when possible and to reduce the load to waste water.

- Optimize the sequence for product changeovers to reduce "start-up scrap" (Dobson, 1992; Göthe-Lundgren *et al.*, 2002).

The team also identified the potential for applying statistical process control (SPC) (Oakland, 2008) in order to reduce over-dosing in product and to react quicker to unplanned process changes. For example, in order to minimize over-dosing of product, the average weight of the units in a given batch should be as close to the nominal weight as possible, but never below the nominal weight (as defined by the Norwegian Metrology Service). If a bottling line has an average of 1063.3g and variation of $\pm$ 1.3, and the

nominal weight is 1063g; then using 1062g and 1064.6g as the lower and upper control limits respectively will result in a quicker response compared to today's specification threshold which is ±16.

Control

Globerson *et al.* (1991) states that "*you can't manage what you don't measure*". As such, the major findings in this project were the identification of weaknesses within the current measurement system. The main focus of the improvement efforts has been on identifying reliable measures and measuring methods and presenting these measures on a weekly basis in order to respond quickly to negative trends, as well as the implementation of standard work procedures and SPC.

Effects

The LSS implementation project at Tine SA achieved the following impacts:

- Increasing the awareness of waste, causes and consequences and knowledge on how to reduce waste.

- Process changes and a new set of KPIs for each department was defined, together with a description of which data is required for each KPI, and the corresponding source of the data. Formulae for calculating the KPIs are also described and an example of how the data should be visualized is shown. One of the weaknesses with the old KPIs is that the nutrients in milk vary with the season, causing a variable yield of different components (such as fat). The variation in fat is accounted for in the new KPIs in order to reveal the true yield.

- SPC was implemented for controlling the weight of finished goods and for dosing the jam into the flavoured milk products.

In terms of quantifying the effects of the LSS initiative at Tine, Figure 3 illustrates that the milk loss (shrinkage to wastewater) has been reduced from approx. two percent before the project (December 2012) to approx. one percent post-project (May 2013). This result highlights the significance that LSS can have, both on improving processes in the continuous process industry and in reducing waste and contributing to a more environmentally sustainable supply chain. Thus, this measure represents the significant impact the LSS initiative at Tine has had on the environmental sustainability of the milk (fresh food) supply chain.
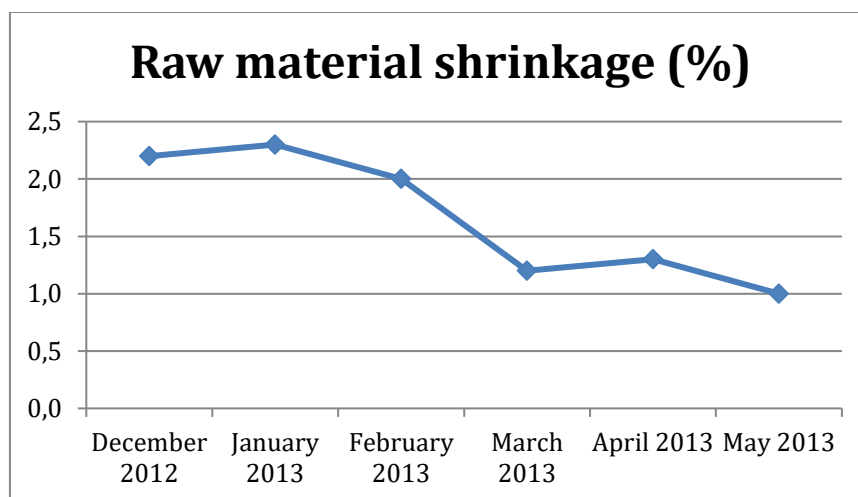
Figure 3: R*aw material "shrinkage" during the LSS project at Tine Tunga*

By adopting a longitudinal field study approach to the investigation, we were also able to identify some of the critical success factors which were considered throughout the project. Firstly, management commitment was crucial to the success of the project. Measuring, root-cause analysis, discussions, communication and awareness were also of critical importance, as demonstrated through multiple workshops with multiple participants. Representatives from all parts of the production were present in order to gain a common

understanding of the complete production process. The idea was that the implementation of the LSS improvement initiative became easier due to such broad involvement. Other learnings from the project were:

- Ensure that the project group has the same goal. The project team should be selected carefully in order to prevent group members from fronting their own interests rather than focusing on the project goal.

- Limit the number of participants to ten people, preferably seven or eight. If the group is too big it is difficult to involve everyone, and it can be challenging to lead the group during group problem solving activities.

- By not having management representatives present during brainstorming sessions, the discussions tend to be more open.

- Find ways to enable everyone to contribute, even those that are quieter during group activities. By allowing time to write ideas on Post-It notes, everyone can contribute.

- The project leader must be able to understand the process in order to challenge the established "truths". Preferably the project leader should be able to participate in gathering facts in order to ensure validity.

- If the company has both Six Sigma and Lean resources it is important that these people can cooperate and appreciate each other's expertise rather than seeing Six Sigma and Lean as competing tools.

- Finding KPI's for each department that the employees themselves can measure and influence is crucial in order to maintain motivation.

Discussion

This work set out to address two research questions: 1) How can Lean Six Sigma be successfully applied in the food processing industry, and 2) How Lean Six Sigma can be

employed to contribute towards creating greater environmental sustainability in fresh food supply chains.

The first research question was addressed by adopting a theoretically sound approach to LSS implementation – what we refer to as VSM-DMAIC. The Lean process mapping technique – value stream mapping – was used to identify the type of waste and where it occurred in the value stream. Then, the Six Sigma DMAIC improvement cycle was applied in order to understand and address the wastes by applying relevant Lean and Six Sigma tools such as root cause analysis, standardized work and SPC. These tools enabled the reduction of waste in the form of milk losses, which demonstrates (by use of a practical example) how LSS can be effectively applied in the food processing industry as a contributor toward the environmentally sustainable fresh food supply chain, thus addressing the second research question.

Compared to other manufacturing industries, the processing industry here represented by a dairy company has challenges due to the fact that the production mainly takes place in pipelines, storage tanks and tapping machines, which means that there is limited visibility of the product. In discrete manufacturing, individual products are simple to identify, handle, measure, and control. This poses a challenge when reducing waste in continuous processing industry in particular, as the length of time and the timing when switching between pipelines, storage tanks and process equipment is critical. The dairy sector also has far more restrictions when it comes to hygiene compared to many other manufacturing industries, as well as the other complications identified previously: perishability, seasonality, and high demand uncertainty which all-in-all makes for a very complex and variable environment for LSS.

A main element in the study has been to investigate the relation between LSS and sustainability in an empirical setting. The relationship and impact of Lean and green

initiatives on companies and supply chains has been debated in the literature, and positive synergies have been identified in studies which are mainly theoretical and conceptual (Garza-Reyes, 2015). By adopting a focus on waste reduction through applying a VSM-DMAIC LSS approach in the raw material processing, bottling and packaging operations at a dairy supplier in Norway, we have been able to demonstrate the positive effects of combining Lean Six Sigma with the green / environmental sustainability dimension (Carvalho et al., 2001).

As such, this work makes two major contributions to the LSS literature. Firstly, the case study acts as a guideline for understanding and deploying LSS in companies outside of the typical discrete manufacturing application area (i.e. the continuous process industry). Secondly, we were also able to make useful reflections regarding some of the critical success criteria that can be used by researchers and practitioners for the effective deployment of LSS in order to contribute towards creating environmentally sustainable, fresh food supply chains. This contributes to extend the validity of the (Lean) Six Sigma DMAIC process (Garza-Reyes et al., 2014; Jirasukprasert et al., 2014) by adding an empirical case study from the continuous process (food processing) industry.

Kovach and Cho (2011) suggests that one of the major sources of variation in food production processes is due to the inherent variability of the measurement system. This work also supports this view in that we too encountered challenges with the measurement system in use at the dairy. We were however able to identify a new set of KPIs for the improved control of raw materials. Though measurement system analysis (MSA) was not performed (due to limitations in the project's scope), it has been identified and should be investigated as a part of further work. Use of new instruments and sensors for improved control of the product in the pipeline is also of interest in order to reduce waste and increase environmental sustainability.

Conclusion

The main contributions of this work are due to the novelty of the application of LSS in the food processing industry as an enabler of greater environmental sustainability, as well as the empirical testing of the VSM-DMAIC approach to LSS implementation in this industry type. We conclude that in addition to the theoretical contributions, this investigation has several managerial implications, and can be useful for both practitioners and researchers, especially when embarking on the deployment of LSS in the food processing industry. For example, we highlight the key success criteria that we believe play an important part in an effective deployment of LSS in the food processing industry. We also illustrate a number of countermeasures which could be relevant for other food-processing companies, such as the importance of relevant KPIs, and the potential of SPC when eliminating wasted raw materials and energy usage in order to contribute to more environmentally sustainable supply chains.

The major limitation of this study is that only one case company was considered. Though the longitudinal study that was adopted provided us with an in-depth account of a single LSS deployment, further work should investigate the potential of the LSS approach in other food processing companies and continuous process industry applications.

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