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Green-Lean Synergy - Root-Cause Analysis in Food Waste Prevention

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ABSTRACT

Purpose_ The goal of this paper is to explore the possible synergetic effects between lean philosophy and green endeavors in improving resource efficiency in the food sector. To that end, it is investigated how a proper and tailor-made adaptation of the lean six sigma root cause analysis method could help in overcoming the complexities of increased resource efficiency in food production.

Design/methodology/approach_ The case study concerned reduction of waste at an industrial production line of a dough-based product, through the implementation of the lean six sigma tool.

Findings_ An achievement of a 50% reduction of waste on the studied process line was reached, thus exceeding the initial improvement goal.

Research limitations/implications (if applicable)_ While the explicit findings on the specific root causes of waste on this actual production line are not immediately transferrable to other cases, they show that applying this method to identifying and eliminating root causes of waste for other products and processes in the food sector could not only reduce costs but also contribute to more resource-efficient and sustainable industrial food production.

Practical implications (if applicable)_ Political and public high interest in environmental and social sustainability associated with food waste render this an important development.

Originality/value_ While the potential of linking green and lean efforts has been acknowledged, the application of the lean six sigma methodology for more sustainable food production has not yet been explored. This paper contributes to this research

Keywords: green-lean; food waste; root cause analysis; Lean six sigma; resource efficiency; sustainable food production

1 Introduction

The food sector is a cornerstone of economic growth and wealth around the world (Romsdal et al., 2011). As the largest manufacturing sector in Europe and the fourth largest industrial sector in Sweden (Livsmedelföretagen, 2014), the food and drink industry has provided 1.9 % to the EU gross value added and excels in terms of employment, turnover, and value added (Food Drink Europe, 2013).

Nevertheless, increasingly important issues of sustainability and other economic developments have made the sector a more challenging environment for the companies.

There have been research studies concentrating on the application of Lean thinking for greening the supply chains because it reduces the amount of energy and wasted by-products required to produce a given product. A number of such studies investigate the relationship between supply relationship, lean manufacturing, and environmental management practices, business performance outcomes, and global supply chain strategies (Simpson and Power, 2005; Yang et al., 2010; Mollenkopf et al., 2010) while another study tries to give an answer to learn the strength of the link between being Lean and being Green (Mason et al., 2008). Another questions the necessity of Lean, investigating the environmental performance of lean supply chains (Venkat and Wakeland, 2006).

In conclusion: Using lean principles to achieve environmental production will also provide considerable cost benefits besides green production since Lean thinking shares common goals with environmental production (Florida 1996; King and Lenox; 2001, Rothenberg et al.; 2001).

Accordingly, exploiting the synergetic effects of green and lean thinking – decreasing the environmental burden at the same time as improving efficiency and cost saving – have become of greater interest to the industry.

The opportunities of working on green-lean synergies have not yet been fully realized, specifically in the food sector where lean practices have rarely been implemented. This paper investigates these synergies. Section 2 gives a background on the state of the art of green-lean synergies in the food industry. It is followed by an explanation of the research question and method in section 3. A case study adapting a stepwise method inspired by Lean Six Sigma in order to reduce food waste are presented and its results elaborated in section 4. Section 5 contains a discussion on the potential and possibilities of dealing with the food waste challenge through root cause analysis and tailor-made adoption of the Lean Six Sigma methodology to respond to the specific requirements and challenges within the food sector. Finally, Section 6 concludes the paper.

2 Green-Lean Synergy in Food Industry

The definition of lean manufacturing stresses the importance of resource efficiency by maintaining the same outputs with fewer inputs, including a reduction of waste (Womack et al., 1990; Dora et al., 2014, Nahmias, 2001; Shah and Ward, 2003). As such, a connection between lean manufacturing and reducing environmental burdens through increasing resource efficiency is an inviting point for studying possible synergetic effects. The benefits from integrating both approaches have been highlighted again and again (Pampanelli et al., 2013; Cobert and Klassen, 2006; King and Lenox, 2001; Porter and van der Linde, 1995; Zokaei et al., 2013; EPA, 2006).

Food waste plays an important part in fostering the synergetic effect of green and lean as it not only is a matter of interest in the industry's economic optimization due to high investments in resources as well as its low profit margins but it also equals a waste of resources such as land, water, and energy mainly at the early stages in primary production where most of the environmental impacts of food occur (Gustavsson et al., 2011). Society's increasing awareness and emphasis on environmentally cleaner products also contributes to the increasing interest (Bansal & Roth, 2000; Faulkner et al., 2005).

However, recent studies of food waste tend to focus more on the end of the life cycle and implementing technical solutions, rather than investigating the potential for preventing waste during earlier stages, before the product reaches the consumer (Schneider, 2011).

To proactively prevent food waste, the root causes need to be detected and eliminated. However, creating a more stable system with less waste is not a straightforward task but rather a very demanding process because of the highly complex and diversified nature of the food and drink industry.

Even investigating a single production line may lead to many diverse possible causes: These include such wide-ranging considerations as managerial decisions at the outset, the technical design of the production line, breakage or failures within the line, lacking climate control, or a multitude of other areas. Moreover, there may not be a single cause but a combination of contributing factors. Therefore, such an investigation requires a large amount of knowledge to ensure stable quality and safe output (Carlos and Oznur, 2011; Wenlock et al., 1980; Kantor et al., 1997; Lebersorger, 2004; Schneider & Obersteiner, 2007; WRAP, 2008, 2009a, 2009b; Langley et al., 2010; Parfitt et al., 2010; Watanabe, 2009; Murthy et al., 2009; Waarts et al., 2011, Stenmarck et al., 2011).

Implementing the lean philosophy in other areas has succeeded in increasing resource efficiency, for example by reducing waste through more stable processes. Applying this methodology to the food industry would likely yield similar results (Folinas et al., 2013). In this regard, the Six Sigma tool can be complementary to the lean approach as the former has proven highly effective in revealing the hidden complexity of ordinary processes and thus exposing the reasons behind variations causing such inefficiencies as food waste.

The purpose of both the lean and the six sigma methods is to reduce variations at the same time as increasing profits, decreasing costs, eliminating defects and waste while keeping quality considerations in mind (Kovach et al., 2011). Lean Six Sigma results from combining the six sigma root cause analysis with the knowledge and understanding of waste reduction from lean thinking. This greatly enhances the ability to determine the root causes of waste (Bendell, 2006).

However, a successful implementation of lean practices depends to a large degree on its context (Sousa and Voss, 2001); that is also the case with lean six sigma method. This context-sensitivity means that a generalized approach, applicable to all companies, does not appear promising (Kochan et al., 1997). Instead, more of a tailor-made approach seems necessary.

Dora et al. (2014) mentioned the challenges faced by the food and drink SMEs in properly adopting lean methods and tools to achieve the originally intended results in spite of potential significant benefits. The lean approach needs to overcome the complexity inherent in the food sector ranging from a wide diversity of products that can perish at significantly different rates; a complicated chain structure with little coordination throughout; various complex processing methods; and finally, consumer demands of the product that can change frequently, due to new trends or awareness of e.g. social or health issues. Yet despite problems such as these, a high service quality continues to be expected by both retail and the consumer.

Customers always expect delivery lead times to be brief, even though processing and packaging lead times frequently exceed these expectations considerably. The latter is also impacted by the fast deterioration of products. This is exacerbated by the food and drink industry relying on forecasts of customer demand rather than specific orders. All of these complex, interactive aspects lead to large inventories being kept, with the accompanying risk of considerable food waste, in order to counteract the risk of a stock out (Van Goubergen et al., 2011; Van Wezel et al., 2006; Roth et al, 2008).

3 The research question and method

As the field is still evolving, the respective literature does not yet offer a wide-ranging view on how lean six sigma manufacturing practices can be tested or implemented in the food industry. The sector-specific difficulties mentioned above need to be taken into account in such studies, in order to improve the applicability of the lean six sigma approach.

Therefore this paper results from action research (Checkland, 1991) studying a specific company with the goal of developing a food waste root cause detection approach based on the Lean Six Sigma method. An action research approach requires the researcher to be involved in the improvement process as a facilitator. Accordingly, in this study, the researcher, as part of the team, is responsible for the improvement process and assists in achieving and implementing the aim of the improvement study.

The target product group is a dough-based product. It is produced at significant volumes, accordingly also yielding significant amounts of waste. Improvements achieved in this pilot project in a major Swedish company are thought to positively affect the entire business and were demanded by the company. The scope of the value chain, in terms of the distance along the chain to be included, was determined pragmatically by the resources available and the company involved (Taylor, 2005). In this case study, the scope includes the first half of the process line, beginning at premixing raw materials to products coming out of the oven. The process is continuous, with a number of sub-process steps ranging from the mixing of ingredients to packaging, including dough mixing, baking, and cooling. All sub-processes have the potential to generate waste if not efficiently run. Primary production, i.e. the farming stage, is not covered in this study.

The reason for choosing this company was that they had some awareness of the concept of Lean. Accordingly, they were interested in hosting a Lean Six Sigma project. The company was immediately positive and after some internal deliberation asked for help in identifying the causes of waste on one specific production line because it had a higher level of waste than other production lines at the plant.

4 Analysis and results:

The Lean Six Sigma DMIC (Define, Measure, Analyze, Improve, and Control) methodology offers a structured, disciplined, and rigorous approach to improving processes. With their interconnected nature, the five steps form a logical sequence that can be continuously repeated for ongoing process improvement. (George, 2002)

1. *Define*

The project goal was to reduce the food waste generated in actual production from 9.6 percent (on average per year) down to 6% (on average per year), a reduction of 37. 5%.

The project was scoped to encompass the first half of the process line, beginning at the premixing of raw materials to products coming out of the oven. Waste was defined to include all food materials wasted as finished or work in progress, excluding packaging material. The members of the core team included experienced production staff, a technician, a product quality specialist, and the experts from SIK.

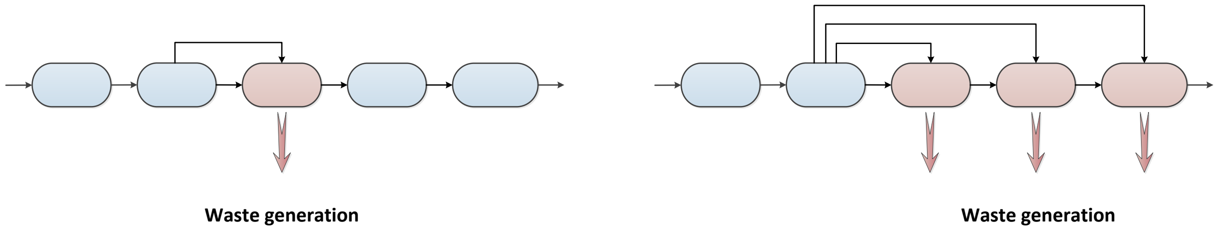

Figure 1. Chain effect (left): The waste is generated by a cause related to other process steps than where the waste is detected. Cascade effect (right): The cause of the waste in several process steps can be related to one single process step.

As illustrated in Figure 1, machinery stoppage can cause cascade effects generating waste in several process steps of a bakery production line. In other cases, root causes of waste may be associated with activities in other management zones of the production line aside from the hotspot of waste occurrence, causing chain effects. Therefore it is of importance to be open-minded to a very high degree of complexity in the root cause analysis and avoid pre-assumptions such as waste being necessarily caused at the site of its occurrence. Observation of the actual process line, conducting interviews and gathering facts from the staff running the daily processes are therefore of major importance to understanding the detailed complexity since these persons know best what incidents frequently occur at the same time as waste is generated in the actual process line.

To further investigate the problem to be solved in this case study, the processing line was first thoroughly observed during operation. Thereafter a kick-off meeting with the core team was implemented, during which a brainstorming session was held. The goal of this session was to gather the long term experience and knowledge from the staff, identifying the wide scope of all possible parameters that may be involved in causing waste at the different process steps on the actual line.

The SIK experts created a process map as a visual representation of the product flow along the line. The parameters from the brainstorming session were classified as either input or output parameters of the different process steps of the line according to the supplier-input-process-output-customer (SIPOC) structure of the Lean Six Sigma methodology (George, 2002; p. 67). The causes that were associated with waste generation at the different process steps were classified as part of the output side of the SIPOC process map. The parameters that could be used to control the causes of waste were put on the input side of the SIPOC process map.

The output parameter that the core team assessed as providing the highest impact on waste generation was the stickiness of the dough. Input parameters that could be used to affect the dough quality therefore became the focus of the measure step. With the main cause of the stickiness of the dough determined, a solution for stabilizing and controlling the process can be found.

2. *Measure*

The goal of the Measure phase was to understand which of all possible input parameters were involved to a high degree in the mechanisms behind the stickiness of the dough. By understanding how these input parameters must be controlled in order to prevent any stickiness of the dough, waste generation can be prevented.

The waste quantities generated during the different process steps within the scope of the study were measured. It was concluded that the greatest amount of waste was produced in the oven.

The result of the SIPOC in the Define phase was that for this specific process line, waste generation often could be associated with the dough's properties; especially, the occurrence of stickiness was concluded to be a parameter related to waste generation. It was also concluded that the dough properties were determined in one or more sub-processes from the oven and upstream to the very beginning of the process line.

Based on these findings, the focus was shifted to the dough-making sub-processes in order to find the root cause(s) for stickiness of the dough.

3. Analyze

To determine which of the input parameters, one or several, identified in the SIPOC were of decisive impact on the stickiness of the dough, the design of experiments (DOE) method (George, 2002; p. 110) was used to conceive a practical experiment at full industrial scale. Due to practical restrictions of the production line, a maximum of 11 full scale experiments could be performed under equivalent conditions (with the other parameters fixed). Thereby, the number of factors able to be studied in the same design of experiments was maximized to three.

Based on the analysis of information from the brainstorming session and the SIPOC structure, the three input parameters considered by the core team as the most likely to affect the stickiness of the dough were chosen as factors. Based on these three factors, the factorial design with three central points and in total 11 experiments was prepared, cf. Figure 2.

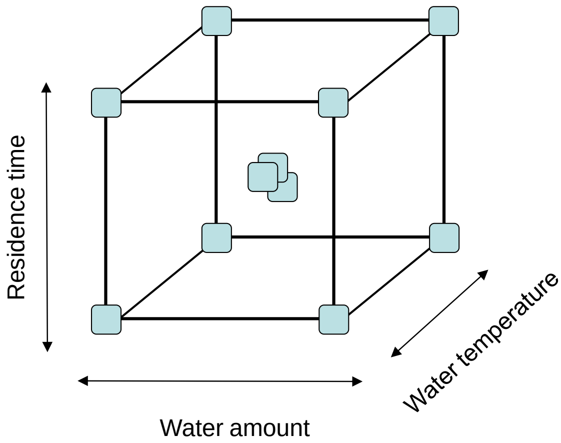

Figure 2. The experimental design

During the full scale experimental work, the factors/parameters were varied under controllable conditions according to the experimental design, and the stickiness of the dough was evaluated for each experiment. To evaluate the dough quality parameter "Stickiness" of the 11 doughs, a category scale ranging from 1 to 5 was chosen. The endpoints "Not sticky at all (1)" and "Very sticky (5)" were defined by the production staff based on their experiences and agreement on the normal quality variation interval of doughs produced on this actual production line.

A statistical analysis of variance (ANOVA) of the experimental results showed that the process parameter "residence time" significantly affected the stickiness of the dough ($p \leq 0,05$). The correlation between dough stickiness and resting time was negative, meaning that settings of the process equipment that gave a longer resting time decreased the dough stickiness. For the statistical analysis, the statistical software Minitab (version 16) was used.

An interview with the staff confirmed that the settings of the residence time often vary. This means that the process previously had not been run under optimal and stable conditions with respect to waste generation.

4. Improve

The root cause of the waste needs to be identified in order to reduce or remove it. Here, the so-called "5 Whys" method has proved useful. Despite the number 5 in the method's name, the process can be repeated as many or as few times as is necessary to determine the root cause (Chen and Shady, 2010). The next step therefore was to continue with a root cause analysis to identify the associated major drivers behind the non-stable use of the parameter "residence time."

The 5 Whys approach was used for the root cause analysis of why the setting of the parameter varied. Interviews were held with the staff and revealed that different persons used this parameter in different ways without any consensus. Some of them were not even aware of the existence of this parameter and therefore did not use it at all. The next Why – why there were such large differences in using this parameter – concluded that there was a lack of knowledge on how to use the parameter to produce a dough with low stickiness and little waste. There was also a lack of routines, instructions, and procedures suitable to control the use of this process parameter to reduce the dough's stickiness and thus also diminish the waste.

The first suggested improvement aiming to reduce waste was to educate and train the staff on how to use this parameter and also to explain why it is important to control this parameter in order to reduce waste. The second suggested improvement was to develop the routines and instructions needed to stabilize the process and how to set the parameter that controls the resting time. These suggested improvements to ensure the setting of resting time to the longest possible option in the process equipment were approved by the production manager and implemented.

5. *Control*

To validate that the improvement was correct and sufficient to achieve the project's goals and also to quantify the effect of the improvement, the waste quantities of this production line were monitored for a test period of 6 weeks. The waste generated on this process line had already been measured earlier, and historical data on the waste levels was therefore available before implementation of these improvements.

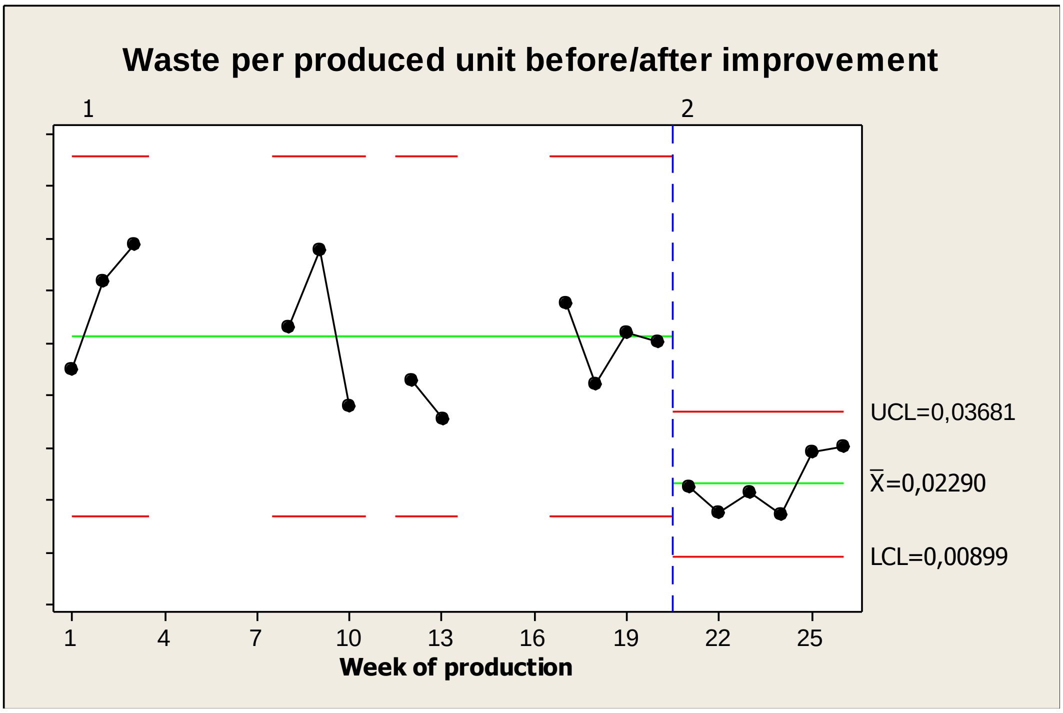

Figure 3. Waste per produced unit before/after implementation of improvement

The green lines in Figure 3 represent the average waste quantities generated on this actual process line. The decrease in waste during the test period after implementation of the improvements corresponds to a 50 % reduction of the waste as shown in Figure 3. This is a far better result than the goal originally set for this project.

It was concluded that the root cause for 50 % of the waste in the actual line had been properly identified and also that it was possible to control this factor over a longer time period. It was furthermore concluded that the correct identification of this major root cause simultaneously enabled not only a lower environmental impact from waste but also cost reduction.

The red lines in Figure 3 represent the interval during which the process varies, thus indicating the stability of the process. It was concluded that not only was the 50 % reduction of waste achieved but also a more stable production process.

5 Discussion

The opportunities of working on green-lean synergies have not yet been fully realized, specifically in the food sector where lean practices have rarely been implemented. Considering the industry's need of dealing with food waste to meet the European Commission's target of a 50% reduction by 2050, it is vital to explore the potentials offered by already developed methods. In light of the sector's dependency on natural resources, reducing food waste would not only lead to decreased cost but also reduce the sector's environmental burden.

Among the available methods and tools, both the lean and the six sigma methods share the purpose of reducing variations at the same time as increasing profits, also eliminating defects and waste while keeping quality considerations in mind (Kovach et al., 2011). While six sigma is excellent in analyzing root causes, it is in combination with lean thinking and its knowledge and understanding of waste reduction that the ability to determine and eliminate the root causes of waste can be greatly enhanced. This combination has resulted in the development of Lean Six Sigma which appears well suited to the application in the food sector (Bendell, 2006).

Yet the diversity of the food sector means that there cannot be a blanket application to all companies. Instead, it is necessary to implement such practices in a customized and tailor-made manner, allowing a company to respond to the specific requirements and challenges within the sector. Expertise in Green-Lean should not stand alone in the implementation but has to be accompanied by the knowledge and experience of the experts working with the processes. Their input is of major importance in understanding the detailed complexity involved since these persons know best what incidents frequently occur at the same time as waste is generated at the hotspots in the actual process line. The involvement of experts, both from staff and the managerial levels, not only improves the processes at the start but also allows these to be kept consistent over a long period. Without appropriate training and employees putting the training into practice effectively, improvement practices are less likely to succeed. Therefore this study targets both researchers and the industry as effective waste reduction can only be achieved by both coordinating with each other and learning to adapt to the specifics of each case.

The aim of this case study was to adapt a stepwise method inspired by Lean Six Sigma (George, 2002) in order to reduce food waste. It illustrates that the potential and tremendous possibilities of dealing with the food waste challenge can be exploited through proper and root cause analysis and tailor-made adoption of the Lean Six Sigma methodology.

In accordance with previous studies (George, 2002; Zhen, 2011; Gunnerfalk, 2006; Svenberg and Torgå, 2007), this case study indicates that the Pareto Principle may be roughly applied to food waste issues as well. The Pareto Principle is also known as the "80/20 Rule". If valid and applied to food waste in a given system, about 20 % of the causes generate 80 % of the waste.

In this specific case, a 50% reduction of waste from the actual process line has been achieved by taking one single action. Correctly identifying the root causes of the major waste quantities and implementing actions towards these may allow an even higher reduction of waste for a specific line. Yet more improvements are likely still possible through eliminating causes with lesser effects. This can be achieved by training both staff and management in the best practices, allowing them to proactively use the cost reduction gained by previous actions as an investment in continuous improvements.

The results achieved in this case study cannot be generalized and validated for all producers of dough-based products as the root cause of waste may vary between production lines, even when the lines are producing quite similar products. This is due to differences in the ingredients and actual machinery used but also based on how physical and human resources work on their own and conjunctly and depending on how the whole process is managed. The root cause of waste can therefore vary significantly case by case. Accordingly, too much simplification would likely be involved in generalizing standards for the whole of the food industry or even the bakery industry.

However, a guideline may be defined on how to map waste in order to identify the hotspots along the part of the food chain under study and the root cause(s) associated with the hotspots. As presented in Figure 4, the analysis starts with detecting the existence of food waste, while the next step is finding the cause of the waste (level 2), leading to an analysis of the root cause or the main driver of such waste (level 1). In the case study elaborated in this paper, the direct cause of waste was found to be stickiness of the dough while the root cause of that traces back to the knowledge of the staff about process parameters. As the waste generation process starts with the root cause leading to the next level of causes and finally ends in food waste as the consequence, the food waste prevention process is the reverse. Based on this type of analysis, effective waste prevention activities for food chains can be identified.

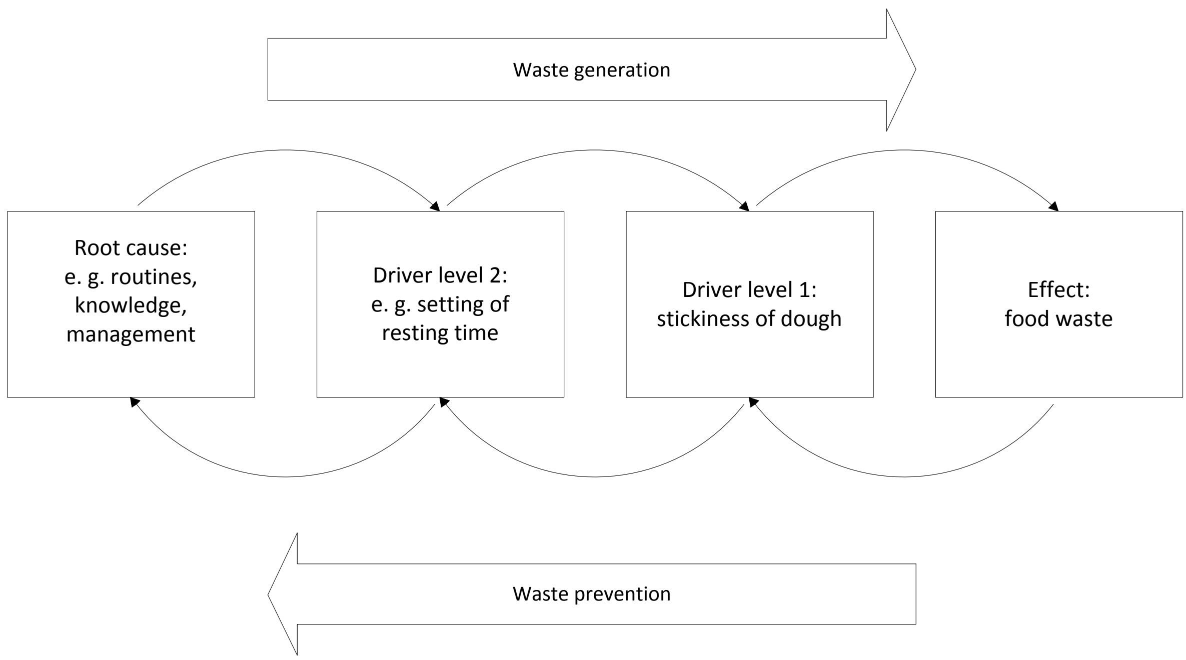

Figure 4. Cause and effect relation

A possible limitation of this study could be its focus on internal processes of the company, rather than encompassing external practices connecting to suppliers or customers. Furthermore, this study has investigated the applicability of the lean six sigma method in a food manufacturing company; a study using more holistic principles - capturing both internal (process) and external (supplier, customer) practices - could be of interest in future studies.

6 CONCLUSIONS

This paper has shown that the possible synergetic effects between lean philosophy and green endeavors in improving resource efficiency can have a significant positive effect – both in terms of costs and sustainability – when applied in the food sector. While the explicit findings with regard to a dough-based product cannot be immediately transferred to other cases and other process lines, the successful application of a tailor made adaptation of the lean six sigma root cause analysis method indicates that a similar approach may yield significant reductions in food waste in other cases. However, it needs to be stressed that the wide range of processes in the food sector requires each approach to be tailored to the specific case.

The literature in the field has previously acknowledged the potential of linking green and lean efforts, yet the application of the lean six sigma methodology for more sustainable food production had not yet been included in this regard. This work has begun to explore the potential benefits from such an inclusion, yet more research is of interest to investigate other applications of lean six sigma and their results as well as a more general examination of deepening the connection between lean and green in the food sector.

Sustainability is a major goal at the present, not only due to the public and governmental interest but also in terms of increasing the efficiency of companies within the food chain and thus their ability to compete. This paper has opened another avenue to assist firms in achieving greater competency and efficiency.

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