sustainability

Article

Improving the Performance of a SME in the Cutlery Sector Using Lean Thinking and Digital Transformation

José Dinis-Carvalho *, Rui M. Sousa *, Inês Moniz, Helena Macedo and Rui M. Lima

Algoritmi Research Centre/LASI, Production and Systems Department, University of Minho, 4800-058 Guimaraes, Portugal; helena@dps.uminho.pt (H.M.)

* Correspondence: dinis@dps.uminho.pt (J.D.-C.); rms@dps.uminho.pt (R.M.S.)

Abstract: The main purpose of this paper is to show that if three specific contextual factors are present in a company, it is possible to achieve great performance improvements with a lean and industry 4.0 implementation. In terms of research methods, a case study was carried out of a project to implement digitalization and Lean practices in a cutlery company, which in fact encompassed a project of master's degree in engineering and industrial management. Thus, the research question is: "It is possible to achieve major improvements in a lean and industry 4.0 implementation if three specific contextual factors are present in the company, namely (i) commitment of top management, (ii) knowledge on digitalization and lean, and (iii) very low Value-Added Ratio?". Regarding the company project, action-research was adopted, and the project team began by mapping and diagnosing the production processes of the two product families (knives and spoons/forks). High levels of work in process, long throughput times, poor flow planning and control, and high stocks of finished products, quickly stood out in both families. Improvement proposals were developed and implemented, namely: (i) creation of a production scheduling and control system, (ii) improvement of the warehouse stock management system, and (iii) adoption of new routines, management tools, visual management, and kaizen meetings. The results achieved were excellent (e.g., throughput time reduced by 27.6% and productivity increased by 36.5%) and aligned with Sustainable Development Goals SDG 9 and 12. The findings of this study corroborate that exceptional results in the company performance can be achieved through a lean and industry 4.0 intervention, if the three referred contextual factors occur.

Keywords: sustainability; lean thinking; industry 4.0; continuous improvement

Citation: Dinis-Carvalho, J.; Sousa, R.M.; Moniz, I.; Macedo, H.; Lima, R.M. Improving the Performance of a SME in the Cutlery Sector Using Lean Thinking and Digital Transformation. *Sustainability* **2023**, *15*, 8302. https://doi.org/10.3390/su15108302

Academic Editor: Paulo Peças

Received: 7 March 2023
Revised: 12 May 2023
Accepted: 15 May 2023
Published: 19 May 2023

1. Introduction

Production flow is a key issue in the Toyota Production System [1], included in the Just-In-Time pillar, as well as it is in the most common excellence models such as Lean Thinking [2], Shingo Model [3], and Toyota Way [4]. Keeping the materials flowing through the processes in a continuous way without stagnation is the most important achievement on the physical side of the production organization and management. Improving flow is achieved by reducing, in a controlled way, the amount of Work In Process (WIP) between processes without losing machine utilization. However, keeping WIP at low levels without losing good machine utilization is not always a simple task as the Kingman formula shows [5]. In complex production environments with a wide variety of products, batches of different sizes, and diverse and alternative routes, it is quite difficult to maintain good performance, both in resource utilization and in WIP or processing time. As these indicators conflict with each other, in order to have a positive evolution, a good balance is needed between the techniques and tools used to keep WIP under control and the contribution of people in the different areas of production (with the right decisions and the right adaptability). In addition to these aspects directly related to the continuous and pulled flow of materials, other principles of excellence need to be implemented for success to be sustainable in the long term. Examples of these principles are, among others, continuous improvement, standardization of tasks, visual management, teamwork, and adapting a leadership style.

The study presented in this paper took place in a cutlery company with 56 employees, in the north of Portugal, which will be referred to from now on as the CR Company, with the aim of showing that the presence of three specific contextual factors (commitment of top management, knowledge on digitalization and lean, and very low added-value ratio) facilitates the achievement of exceptional results in terms of production system's performance.

As there was a slight reduction in demand and difficulties on the production unit during the COVID-19 pandemic, the managers decided to apply the Lean philosophy as best as possible to improve the company's long-term sustainability. They had been aware for some time of permanent problems in the flow of materials, enormous difficulties in meeting delivery deadlines, and of some chaos on the shopfloor. For all these reasons, and to meet the proposed challenge, the managers decided to involve a final year master's student in industrial engineering and management, to develop his dissertation in the company, and to request the help of an external Lean consultant.

The defined objectives for the CR company project were quite challenging as they included the reduction of WIP and throughput time by 50%, improvement of the average productivity by 20%, improvement of the Value-Added Ratio (VAR), and a 30% reduction of stock in the finished product warehouse. Moreover, in this particular case, efforts will be made to continue to introduce improvements over time and for this reason it was determined to reassess the effect of the project one year after its completion. The research question in this study is: "It is possible to achieve great improvements in a lean and industry 4.0 implementation if three specific contextual factors are present in the company, namely (i) commitment of top management, (ii) knowledge on digitalization and lean, and (iii) very low Value-Added Ratio?".

Previous works have shown positive relations between the implementation of Industry 4.0 principles with green, lean and resilience in industrial companies [6,7], which reinforces the importance of the main guidelines, decided by the managers, to be followed in this project: (i) use as much as possible the principles presented in the excellence models, (ii) create continuous improvement practices and culture, (iii) pursue social, economic, and environment sustainability, (iv) apply digitalization and connectivity, and (v) apply standardization and visual management. Thus, it is expected that these principles will help resiliently sustain the operational and green improvements in the company.

2. Theoretical Background

The world economy depends heavily on small and medium-sized enterprises [8]. However, these companies, when compared with larger ones, face more challenges related to key resource constraints, low productivity, and great environmental impact. These business characteristics, the current market conditions and the growing pressure on the organizations to improve their environmental and social performance, force them to pursue strategies to be more competitive and sustainable [9]. Moreover, in 2015, the 2030 Agenda for Sustainable Development, which is centered on the 17 Sustainable Development Goals (SDG), was endorsed by all UN Member States, shaping a framework for development that focuses on eradicating poverty and deprivations, improving health and education and spur economic growth while tackling the degradation of environmental resources for all [10]. Within this framework, several goals are focused on production improvement, including SDG 9, which seeks to promote sustainable industrialization, innovation, and infrastructure. This goal is crucial for advancing technological progress and promoting sustainable production processes, which can help reduce the negative impacts of industrialization on the environment. Another relevant goal is SDG 12, which focuses on responsible consumption and production [11], aiming to reduce waste, increase resource efficiency, and promote sustainable practices in production and consumption. Achieving these two goals is crucial for improving production processes, reducing environmental impact, and creating more sustainable supply chains [8,9].

Following the economic instability felt at the end of World War II in Japan, the automobile industry has changed its fundamental ideas about production organization and production management. Just as mass production dissipated craft manufacturing, a new production system emerged in the automotive industry—the Toyota Production System (TPS) -, breaking the prevailing paradigm at the time [12]. The TPS concept was developed by Toyota Motor Company, in an environment where resources were limited, in such manner that its main goal was to achieve a reduction of production costs through the elimination of waste (Muda). Waste in this context is described by Ohno [1] as all actions that, from the perspective of the final customer, do not add value to the product. He categorized these activities into seven categories: overproduction, transportation, waiting, inventory, over-processing, motion, and defects. Later, in 2004, Jeffrey Liker entitled an eighth waste, which describes the lack of utilization of employees' creativity in continuous improvement, considering the loss associated with not taking advantage of ideas, or growth opportunities, due to the lack of employee engagement [4].

The term "Lean Production" was introduced by MIT researchers [13] to depict the adoption of TPS by occidental companies. Thus, a Lean Production system is a system that strives for perfection, constantly focusing on reducing costs, achieving zero defects and zero inventory, while producing a wide variety of products [12].

Throughout the years, the Lean Production paradigm, which was characterized by producing more, with more quality using fewer resources, and less time and waste, evolved to Lean Thinking which is founded on five guiding concepts that serve as the cornerstone of every Lean initiative [2]: (i) define value from the perspective of the client; (ii) identifying the value stream; (iii) creating a continuous flow; (iv) applying pull production; and (v) chasing perfection (continuous improvement). Furthermore, the management of materials and information flow, takes a crucial role not only in Lean philosophy, but also in other excellence models such as Toyota Way [4,12] and Shingo Model [14–16]. To better explain the creation of flow in manufacturing companies, an analogy is often made to a river flowing with or without rocks. Obviously, the river flows more smoothly if it has no rocks; in the context of manufacturing, the river can be compared to the production process and the rocks to the bad data, poor training and communication, and lack of standards and metrics. If a continuous flow can be achieved, the throughput times, WIP, and wastes will be reduced. The Value Stream Mapping (VSM) tool has proven to be very efficient in portraying these flows of information and materials, as well as in identifying opportunities for improvement [17]. Moreover, tools such as Waste Identification Diagram (WID) can also be used with the same purpose [16,17]. Both VSM and WID pay great attention on WIP because the higher it is, the lower the flow of materials along the processes, which is one of the most important principles of Lean thinking and other models of excellence. The main objective is to reduce WIP because this reduction has a positive impact on throughput times, quick response to the market, better use of space and higher productivity.

Continuous improvement, or pursuing of excellence as it is called in Lean Thinking (the fifth principle), is a core principle in the main excellence models. The role of this principle is that even if a company performs well, is competitive, and dominates the market, nothing lasts forever, and so it must anticipate the future, adopting strategic measures following the philosophy that everything can be continuously improved, whether they are processes, products, or services [2]. All staff members must be engaged in CI on a variety of levels for it to be effective. Direct collaborators are the ones who are best able to identify the difficulties and problems that arise in the course of their work, and their teamwork and involvement are crucial in order for them to start making improvements to the organization as a whole [18,19]. Along with this, the management of the business must support all attempts for improvement and change and must guarantee that employees are respected from the start [4,20–22]. The creation of a continuous improvement system [23,24] with visual management, teams, and daily meetings with a standardized schedule are some of the methods considered effective for increasing employee involvement [25]. Although there is no consensus on the best practices for getting employee engagement and involvement, continuous improvement is a duty to all employees. Furthermore, the establishment and monitoring of Key Performance Indicators (KPI) is essential to effectively measure the progress of continuous improvement and Lean implementations; in fact, without a standard one cannot know whether improvement has occurred or not [24–31].

Recently, the dissemination of Information Technologies and the transition toward the adoption of Industry 4.0 technology has pushed companies to move forward digitalization [32]. Case studies, particularly those from large enterprises, have shown that several businesses are utilizing digital technology to take advantage of their surroundings and process a higher amount of knowledge that has been gained and/or created internally [33]. Researchers have also demonstrated that digitalization affects companies' capacity to search information, absorb knowledge and make decisions.

Tablets and other digital devices can be used to monitor and manage the flow of materials in a manufacturing system, providing operators with real-time information on the status of production, which enables them to make the most appropriate decisions at any given time and improve company performance [34]. They can also be used in an Industry 4.0 manufacturing system to connect equipment and systems, enabling information sharing and communication between them. As problems may be rapidly discovered and fixed, this can increase efficiency and reduce downtime. Additionally, tablets can be used to access data from sensors and other monitoring tools, giving users insights into the functionality of their equipment and facilitating predictive maintenance.

Digital Lean is a relatively new concept, which combines the principles of Lean Manufacturing with Digital Technologies [34,35] to help companies achieve higher levels of productivity, quality, and flexibility, i.e., higher levels of operational excellence [31,32]. Lean and Green 4.0 is an approach that combines the principles of Lean Manufacturing and Green sustainability practices in the context of Industry 4.0 [36].

Industry 4.0, Digital Lean, Lean and Green 4.0 and sustainability are closely linked, as they all focus on reducing waste, increasing efficiency, and minimizing environmental impact. The integration of digital technologies with Lean principles can help companies reduce their carbon footprint by optimizing processes, reducing energy consumption, and improving resource utilization. Additionally, Digital Lean and Lean and Green can help companies meet sustainability goals by improving the quality and durability of products, reducing the use of harmful materials, and optimizing supply chains to reduce transportation and storage costs. Overall, the adoption of these approaches can help companies achieve operational excellence while minimizing their impact on the environment, making it an essential component of sustainable business practices [33–35]. Several scientific studies have investigated their benefits [7,33–41]. For example, a study published in the Journal of Cleaner Production found that the implementation of Lean and Green practices in a manufacturing company resulted in a reduction in energy consumption, waste production, and greenhouse gas emissions, while also improving product quality and customer satisfaction [39]. Another study published in the International Journal of Production Planning & Control found that incorporating Green principles into Lean production processes can lead to cost savings, increased productivity, and improved environmental performance [41]. These findings suggest that Lean and Green 4.0 is a promising approach for achieving sustainable manufacturing practices while also improving operational efficiency. Despite all this, for success to be achieved some critical success factors must be ensured. The creator of the Kaizen model, Masaaki Imai, often mentions in his lectures that the three critical factors for kaizen (Lean) transformation are: "Top management determination", "Top management determination", and "Top management determination" [42]. A very similar success factor "Dedicated management and employees" appears as the most relevant one by Mrigendra Mishra [43], regarding the implementation of Green and Lean six sigma. From the same publication, another of the top five success factor that should be mentioned is "Facilitate resources and skills for implementation". A literature review [44] also concluded that the "Management involvement and commitment" is the most important factor for the success of Lean Six Sigma implementation. The other factor related to skills also appears in the list as "Understanding tools and techniques" as medium-priority critical factor. The factor "Top management support and commitment" does not always appear on the top position [45]. In the same publication the factor "Skill and expertise" appears on the 12th position.

From the perspective of barriers that prevent lean implementation success, lack of leadership and top management commitment, lack of systemic understanding of lean, lack of lean expertise and training were found to be the most critical causal barriers [46].

Lean philosophy and digitalization are expected to have a positive impact on productivity, but in the context of this study, it is important to note that company productivity has a direct impact on environmental, social and economic sustainability. When a company is productive, it is able to produce more goods and services with fewer resources, thus reducing the consumption of raw materials, energy, and water, as well as the generation of residues and pollutant emissions [47]. In addition, productivity can also lead to cost savings, increasing the firm's competitiveness and profitability, which in turn can contribute to economic sustainability [48]. However, it is important to note that productivity should not be achieved at any cost, especially if it means sacrificing environmental and social sustainability [49]. Companies must seek a balance between productivity and sustainability, considering the complex interactions between economic, social, and environmental aspects. In this regard, implementing sustainable practices, such as reducing waste, using renewable energy sources, and managing the supply chain responsibly, can lead to increased productivity and efficiency while contributing to sustainability [50].

3. Method

In terms of research methods, the work presented in this article is a case study developed at the CR Company. However, all this work had its origin in a project proposed by the CR Company, to improve the performance of its production system, and which was developed by a final year student of the master's in industrial engineering and management. Considering this purpose, the research-action method was adopted for the project in the CR company, as it should tackle real organizational problems, involving the organization stakeholders [51] with the researchers, aiming to solve identified problems, and improve organizational performance [52]. For this paper, the case study methodology was adopted, precisely about the referred improvement project. It is interesting to mention that, according to Coghlan & Brannick [53], although action research can be seen as a live case study, it can also take the form of a traditional case study reported retrospectively. A project team was set up by the CR Company that included the student, an external lean consultant, and a senior manager from the company (production manager). The project lasted six months and took place in the year 2020. The university's institutional master protocol was established with the CR Company, defining rules, rights, and duties for both parties. The information collection was carried out in the shopfloor as well as in the company's existing documentation and was processed and analyzed with common tools (spreadsheet).

The phases of the research were inspired in a very popular model presented by Mike Rother [17,54], commonly used in Lean environments. The phases are then as follows:

- Grasp the current condition—in this first step, the researcher, the consultant and other team members had to know the products, the production process of each product family, the flow of materials, the layout, etc. Several analysis and diagnostic tools can be used, such as flowcharts and Value Stream Maps (VSM) to describe the global flow of the products through the production steps. The current performance will be assessed using the following key performance indicators:
    - Stock of finished goods and WIP;
    - Throughput Time (WIP/daily demand);
    - Value-Added Ratio (Total processing time/Throughput time);
    - Productivity (production/man.hours).
- Establish a target condition—the target condition can be translated into the following performance improvements:

 - A 50% WIP reduction;
 - A 30% reduction in finished goods inventories;
 - A 50% reduction in throughput time;
 - A 50% increase in the Added Value Ratio;
 - A 20% increase in productivity;
 - Implement continuous improvement routines, entities, and artefacts.
- Identify improvement opportunities in the target condition direction, define improvement actions and implement them—The concepts, rules, and techniques associated with excellence models like the Toyota Way, Lean Thinking, and Shingo Model will be used to construct the improvement actions;
- Check the results at the end of the project—compare the initial performance indicators to target conditions. Based on that, the researchers and the company representatives will draw some conclusion and decide upon next steps;
- Check the results one year after the end of the project.

4. Results

4.1. Grasp Current Condition or Initial State

All products that are produced in the production unit in question belong to two families, the family of knives and the family of spoons/forks. The family of spoons/forks include dinner spoons and forks as well as coffee spoons. These products use the same raw material and follow the same production process, depicted on the left side of Figure 1. The family of knives includes dinner and dessert knives because they share the same production process route as depicted on the right side of the same Figure 1.

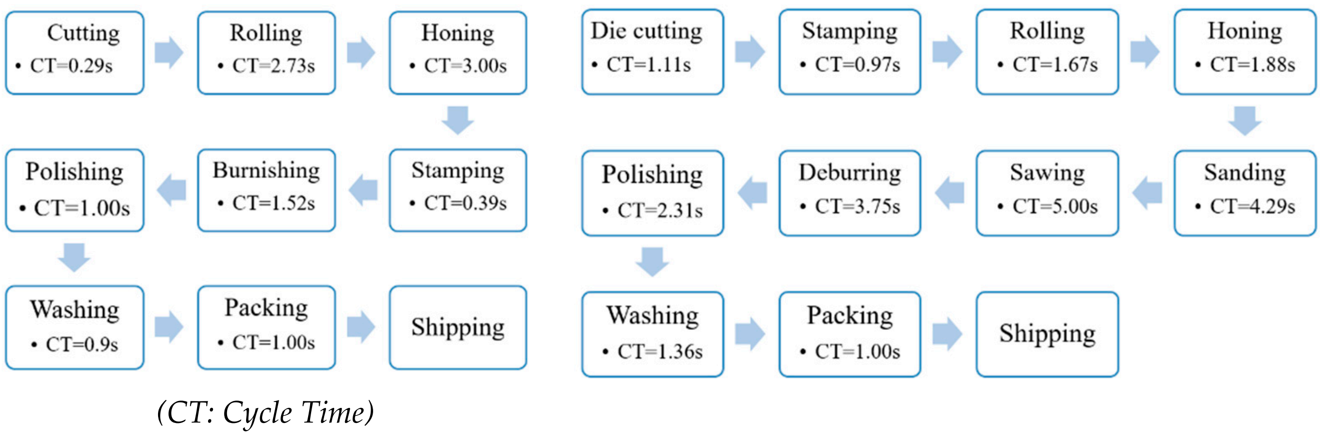

Figure 1. Production process of spoons/forks (**left** side) and knives (**right** side).

To include in the same visual representation more information than just the process route of each family, the team for this project resorted to VSM. This type of representation is richer in information and serves as a platform to communicate, discuss and identify problems and opportunities for improvement. One of the aspects that most clearly stands out in a VSM is the issue of fluidity or lack thereof, represented with WIP and throughput times, which are key aspects in this project.

Two VSM were created to represent the reality of the production flow, one for the family spoons/forks (Figure 2) and other to the family knifes. For the sake of clarity and dimension of this article the latter is not presented here. One of the main problems that can be easily noticed in the VSM (Figure 2) is the large amount of WIP and consequent long throughput time. This problem is identified in the VSM with the yellow tags nr. 1 (Figure 2).

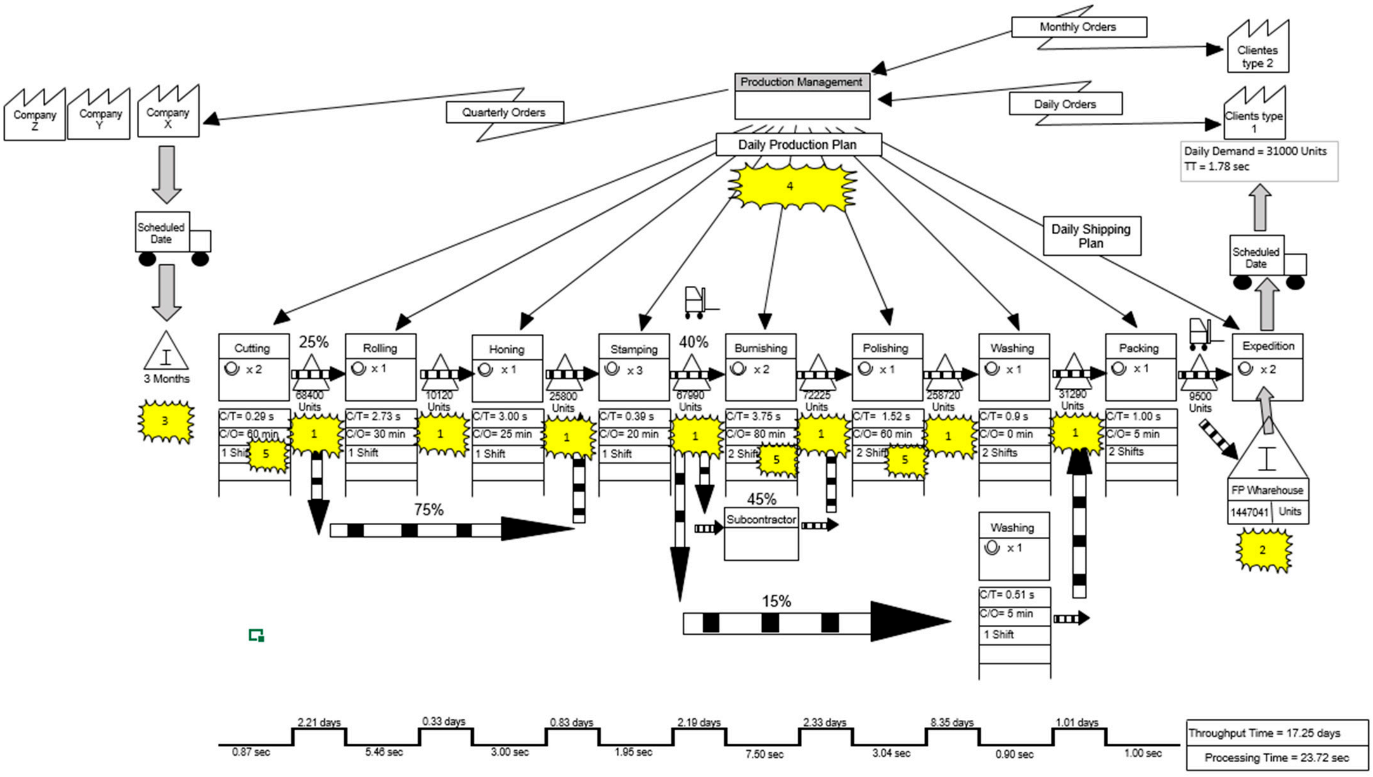

Figure 2. Initial VSM for spoons and forks family.

Data was collected during 2 days of production stoppage to establish the current condition or initial state of the WIP quantities along the various steps of the production processes. WIP values were obtained by observation, in the shopfloor, carried out by the researcher with the help of team leaders. With the WIP values (537,045 units of the spoons/forks family, and 130,370 units of the knives family) it was possible to estimate throughput time for each family, since the demand was known for each family (31,000 spoons and forks and 10,500 knifes per day). Resorting to an adaptation of the Little's Law [55], expressed in Equation (1), for the family of spoons and forks, a throughput time of 17.3 days was projected, and for the family of knives, a throughput time of 12.4 days.

$$\text{Throughtput Time} = \frac{\text{WIP}}{\text{Daily Demand}} \quad (1)$$

These values for the throughput times do not include the waiting time of the raw materials in the warehouse nor the waiting time of the final products in the respective warehouse. These long throughput times were forcing slow response to market and poor service.

To measure and establish the reference of the quality of the flow for the materials in the shopfloor, the team decided to use the Value-Added Ratio (VAR) as an adequate indicator, expressed by Equation (2).

$$\text{Value Added Ratio (VAR)} = \frac{\text{Total Processing Time}}{\text{Throughput Time}} \times 100 \quad (2)$$

Considering the total processing time of 23.72 s required to produce a spoon or a fork (Figure 2), the VAR for this product family was of 0.0025% (Assuming 920 min of work per day; two shifts of 8 h with 20 min of breaks). For the knives family the VAR was of 0.0054% (the throughput time is 12.4 days). These values are extremely small, compared with the reference value of 5% for world class manufacturing companies [56,57]. These low values for VAR show clearly a problem related to the lack of flow. The products in the production process spend more than 99.9% of time just waiting in different queues.

If the stock of finished products is also considered for the throughput time calculation, the results are even more worrying (see Table 1). The amount of finished goods in stock is also extremely high, being considered a problem to be addressed in this study. This problem is identified as an improvement opportunity represented by the yellow tag nr. 2 in the VSM of Figure 2.

Table 1. Total Throughput Times for spoons/forks, and knives.

Products	WIP	Stock of Finished Products	Dailly Demand	Total Throughput Time (Days)
Spoons/forks	537,045	1,447,041	31,000	64
Knives	130,370	576,600	10,500	67.3

Raw materials stock is also a problem, indicated by the yellow tag nr. 3 in the VSM of Figure 2. Raw materials are typically ordered for 3-month periods. Another identified problem is related to production planning and scheduling procedures and practices (yellow tag nr. 4 in Figure 2). Local decisions are daily taken for different reasons such as to accommodate local optimizations, capacity variations, or urgent orders, resulting in poor performance and waste, e.g., some production orders are produced too late while others are produced too early. Furthermore, there are many communication problems between the production planning and control system and local supervisors.

Table 2 summarizes the main identified problems in the value stream, the associated yellow balloon number in the VSM, the negative impact in the production performance as well as the type of waste associated with each one of them.

Table 2. Problems identified through the value stream.

Problem	Tag Nr.	Consequence	Waste
High WIP	1	Occupied area on the shop floor; Shop floor chaos; Lengthy throughput times of 17.3 and 12.4 days (for knives, forks, and spoons).	Overproduction Inventory Waiting
High levels of Finished Product Stock	2	Occupied area on the finished products warehouse; Dead capital investment: 2,023,641 product units in a warehouse.	Inventory Overproduction Motion
High levels of raw material stock	3	Occupied area of the raw materials warehouse; Chaos on the warehouse	Inventory Transportation Defects
Inefficiency and lack of information in production planning	4	Wrong production decisions and poor delivery service; Loss of time looking for data on production scheduling and routing	Waiting Overproduction Defects
Long setup times	5	Time spent on non value added activities; High WIP; Low productivity	Overproduction Waiting
Excessive motion and transports	Not in VSM	Low productivity	Motion Transportation
Low Productivity	Not in VSM	Workers spend much of their time dealing with nonvalue adding activities	Motion Transportation Defects Waiting Overprocessing

4.1.1. High Work-In-Process

The first problem or improvement opportunity indicated by the yellow tag nr. 1 in the VSM in Figure 2, is related to high WIP levels throughout the production process, especially between the polishing and washing processes for spoons and forks (this WIP is responsible for 8.35 days in the total throughput time). The necessity of washing particular models in a machine that is only operational on certain days of the week is the primary contributor to this accumulation. High WIP values also exist in other locations, although to a lesser extent, due to other causes. Inefficient planning, lack of WIP limitation mechanism and inefficient production monitoring and control were identified as root causes of general high WIP. Apart from the classic problems related to high WIP (e.g., space occupation, long throughput times, excessive handling, time wasted in searching for material, and waste with motion and transportation), in this case there was another worrying reality: some production orders would end up being forgotten forever in the middle of so much stock. This forgotten WIP was identified when checking the condition of each of the batches parked in all sections of the plant.

An estimate of the average value of the products in WIP is presented in Table 3. As can be seen, around €400 k are permanently tied up in the form of materials waiting. This amount of money cannot be used for anything else and so there is a loss of opportunity due to this mismanagement of material flows. The throughput time resulting from high WIP represents another very negative effect on the business. Long throughput times lead to difficulties in meeting deadlines, i.e., a worse response to the market.

Table 3. Value assessment for WIP.

Product Category	Average Unfinished Part Cost (€)	WIP (Units)	WIP (€)
Spoons/forks	0.55 €	537,045	295,374.75 €
Knives	0.80 €	130,370	104,296 €
Total			399,670.75 €

The current value of the throughput time is perceived to be very high because the VAR is very small, as argued in Section 4.1, making this a problem that needs to be addressed.

4.1.2. High Stock of Finished Products

The strategy of the company in its response to the market mainly involves Make To Stock (MTS), but also includes Make To Order (MTO). The advantage of MTS lies in being able to respond immediately to customers directly from stock, for some products. The MTO allows to satisfy the market for specific orders for which there are not enough quantities in stock. It turns out that in the CR company, production orders for restocking were defined intuitively and very often according to the conditions at the time of the decision. The existing errors in the information about the stock levels of the various products, as well as the delays in the update of the stocks, also contributed to the enormous inefficiency of the management of the finished product stocks, resulting in exaggerated stock levels for some products (yellow tag nr. 2 in Figure 2).

The stock holding cost associated with over 1.2 M€ in finished products and the large area occupied are sufficient motivation to welcome a reduction in stock quantities.

4.1.3. High Stock of Raw Materials

The third problem, indicated by the yellow tag nr. 3 in the VSM (Figure 2), resulting from observation and through conversations with managers and employees, is the high stock of raw material existing in CR company. One of the main causes of this problem is the fact that, in the case of cutlery (spoons/forks), there are many different sheet metal coil references to meet the different specifications of the finished product and the way the press cutter is designed. For each product, a new press cutter must be designed, and the result is the need of a sheet metal coil with a specific width. As can be seen in Figure 3, the different cutter specifications for sheet metal coil results in the need to purchase many different coils with various widths.

Figure 3. Examples of different press cutters.

In February 2021 there were 100 different references of sheet metal coils, requiring a significant amount of storage space and high stock holding costs. This warehouse had to be recently expanded, exactly because of the growing number of different sheet metal coils that need to be stored.

4.1.4. Ineffective Production Planning and Control

The person responsible for Production Planning and Control (PPC) decides daily what is produced, and in what quantities and sequence. However, there are often miscommunications between him and the local supervisors and managers, which leads to ineffective production sequences and poor performance. In addition to this problem, the fact that the production manager does not use the computer system to help in planning, makes it impossible for him to give answers regarding delivery dates or even processing times. An auxiliary excel sheet is used to determine in which machine the cutting will be performed for each production order, and from there, the local manager decides production sequences with local optimization logic. So, in reality, the decision upon with order will be executed is taken just when a machine becomes available (yellow tag nr. 4 in Figure 2). This practice has led to large WIP and long delays in production orders.

4.1.5. Long Setup Times

The fifth and last yellow tag in the VSM identifies the long setup time of some machines and the effects of that in WIP and overall performance. At CR Company, most machines require several tuning changes from one product reference to another. Furthermore, few operators can perform the setup of a machine without the help of the local supervisor or another more experienced operator. Since the planning is inefficient, the operator often does not know which product to produce next and the setup takes long time because there is no prior preparation of the necessary tools for that specific setup.

4.1.6. Excessive Motion and Transports

The cutlery produced in CR Company, starts production in pavilion 4 or 5, and always ends in pavilion 1. Both products and operators are obliged to travel long distances to transport the parts between machines that can be located in different pavilions. However, a problem identified during the project, related to movements, was the fact that most stamped parts (spoons and forks) must be transported from pavilion 5, where they are produced, to pavilion 3 to be delivered to a subcontractor. On average, the supervisor for the cutlery section (pavilion 5) must travel twice a day between those two pavilions, to transport the stamped parts destined for the subcontractor. This transport was observed 3 times, and it takes an average of 15 min, representing thus a total expenditure of 45 min per day.

4.1.7. Poor Productivity

The researcher was able to determine from field observation and performance indicator monitoring that the organization was having trouble delivering on time, which was a sign of both high levels of WIP and low productivity. Together with the process's high amount of WIP, other factors that have an impact on this key performance indicator (KPI) include long setup times (Section 4.1.5), excessive motion, transports, waiting, and defects. Another issue is poor communication between the production manager and the section managers, which causes delays in the execution of production orders (POs) and even the production of goods that don't match the specifications. Forgotten POs are also to blame for the "forgotten" WIP that is present on the factory floor and in the warehouse where finished goods are stored. Other factors that were influencing the performance of setup tasks were poor planning and a lack of communication. In this regard, the operators frequently did not know what product or model they would produce next, so the setup tools were not prepared in before. In order for the operators to know what product the team should use, they must speak with the section manager. The lack of location information and the fact that the tools were not stated in the POs hampered the process further because it required the operator to hunt for someone who knew where the tools were kept or simply knew which tool to use. Table 4 displays the daily setup time based on the typical reference values used by the company.

Table 4. Average (Avg) daily time spent doing setup tasks.

	Avg Daily Amount of Setups		**Avg Setup Time (min)**		**Avg Daily Time Spent on Setup Tasks (min)**	
Operation	**Spoons/Forks**	**Knives**	**Spoons/Forks**	**Knives**	**Spoons/Forks**	**Knives**
Cut	7	1	60	10	420	10
Rolling	1	2	30	25	30	50
Deburring	1	2	25	35	25	70
Stamping	7	2	20	30	140	60
Sanding	-	3	-	5	-	15
Knurling	-	2	-	15	-	30
Burnishing	3	2	80	45	240	90
Polishing	9	7	60	60	540	420

It is clear that a lot of time that could be used to produce products is used in setups. The most serious case is the polishing operation, where 9 h per day (in two shifts) are spent on setups for the spoons/forks family and 7 h for the knives family. Additionally, the project team measured the productivity for one month. The company produced 585,347 units in that month requiring 45 workers with an average of 288 h per worker. Thus, the average productivity was 45.17 units/man.hour.

4.2. Improvement Opportunities Development and Implementation

After having identified problems and opportunities for improvement in the previous phase, the project team started to develop and implement some changes in order to pursue some common principles and practices associated to the main excellence models, such as Lean Thinking. Visual management, standard work, teamwork, pull production, and KPI monitoring are a few examples. Production planning and controlling also underwent through certain adjustments.

4.2.1. Production Orders Monitoring and Control

One of the key goals of this project was to reduce the amount of work in progress that is typically dispersed over the shop floor. As this reduction has positive effects on the reduction of throughput time, reduction of occupied space, and improvement in productivity, the project team reserved full attention to it from the start. One of the recognized causes of high levels of WIP was the existence of batches forgotten on the shopfloor. It was necessary to define their production status and determine the operations missing to complete their processing. After that, the production manager and the supervisors of each section set in motion a plan to finish all the forgotten batches and catch up on all production orders. The period was perfect because the COVID-19 pandemic contributed to lower the demand reducing the pressure on production.

After everything has been arranged regarding ongoing production orders and customer commitments, the important thing was to find a way to maintain low WIP levels and good material flow. Digitalization and connectivity between different resources were understood as tools to be implemented. A system was then designed and implemented to monitor and allow the control of the flow of materials. One tablet was assigned to each supervisor of the different production areas, linked to the centralized PPC system, providing the information about production planning, sequencing and scheduling, helping them in the local management and allowing workers and supervisors in the introduction of relevant production data back to the system. In terms of data sent to the shopfloor, a list of production orders sequenced by due date is created and sent every week to the polishing and cutting stations. The polishing station was identified as the key station as it acts as the pacemaker ("drum") of the system, and the cutting station for being the first station in the sequence. All other stations just follow the FIFO (First-In First-Out) rule as the orders arrive to stations queues. The production manager also sends a daily schedule to every machine. To control the production flow, operators access tablets with that schedule (Figure 4), i.e., the sequence of orders to be followed, and select the one to be processed next (from left to right and top to bottom; each green rectangle represents a production order). When starting an operation, the operator introduces the time spent on setting up the machine and then performs the operations required for that order. When the operations are concluded, the operator indicates the quantity of parts produced, parts sent to scrap and parts to be reworked.

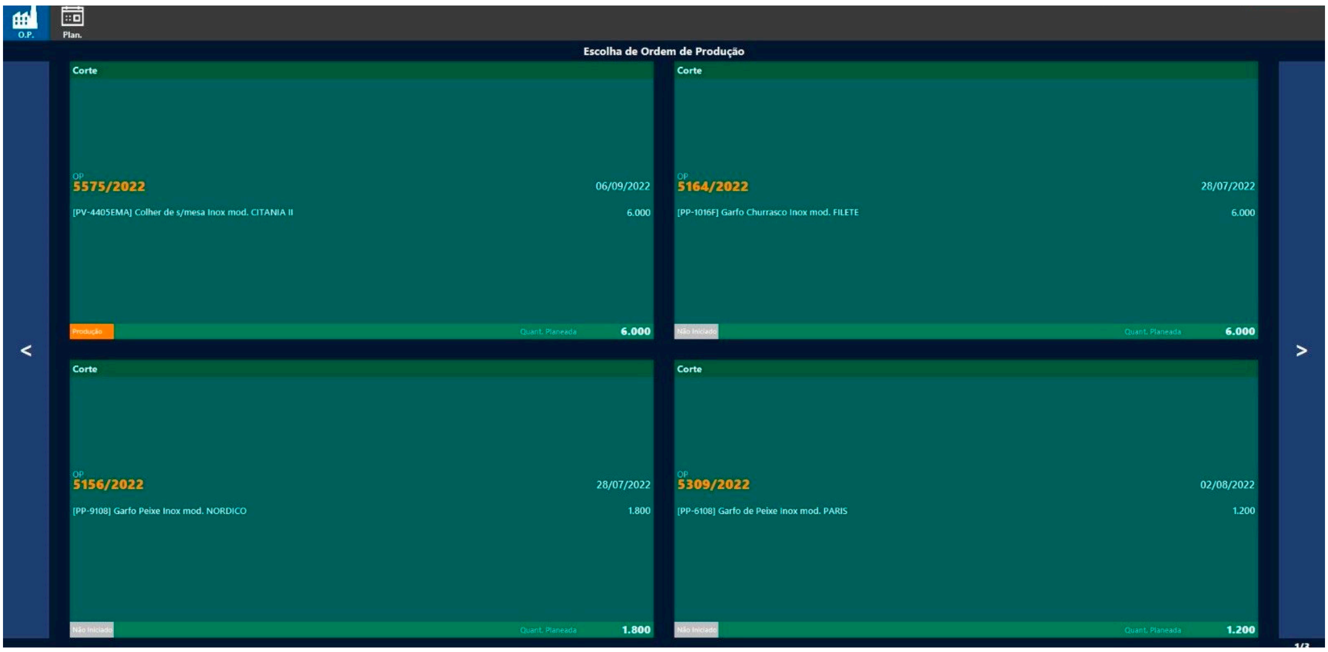

Figure 4. A screenshot of the operator's tablet screen with 4 existing orders to be processed.

With this system, the productivity was improved since several types of waste were eliminated or reduced. Everyone knows what to do next and no operator wastes time looking or waiting for information. There are no wrong production orders being processed to be forgotten somewhere in the factory.

4.2.2. New Stock Management Practices for Finished Products Warehouse

Existing data on quantities sold for each type of product, as well as internal delivery times, made it possible to more precisely determine safety stocks, reorder points and replacement quantities for each final product. An excel file was created with the demand profile as well as internal delivery times for each product. This data makes it possible to automatically determine safety stocks and reorder points for each product, considering the updated demand profile and changes in delivery times.

This excel file provides the production manager with an ordered list of priorities for generating production orders so that stock levels of finished product are kept at low levels, yet with a low probability of stock-outs. This file also provides visual alerts if some orders are critical, by showing them in red color in the list.

4.2.3. New Approach to Raw Material Stock Control

To solve the problem of high levels of raw materials stock, two improvement actions were implemented. The first one was the reduction of different sheet metal coil widths. The design of the press cutting tools is now limited to a list of metal sheet widths. After some time with these limitations, the number of different metal sheet coils in the warehouse was reduced from 100 to about 70 units.

A second action was focused on a better stock management. The calculation of raw material consumption in the cutting operation was developed for all the cutters in the company. The quantity of raw material needed for each product reference was determined in detail. With that information, the quantity of raw material needs for a certain production period is accurately determined based on the master production plan for that period. A database was created with the raw material consumption of all products in the catalogue, which was connected to the production planning and control software and could be consulted by all people involved in the process. An Excel spreadsheet was also created, linked to the production planning and control system, where all the references that would start production in the following months were listed. In this way, the search for raw materials is made according to actual needs and not based on forecasts, as was done previously.

4.2.4. Other Improvements

Fine-tuning the machines, an important part of the time spent setting them up, was seen as an improvement that could be implemented at very little cost. The main problem identified was the lack of any kind of pattern during setup. Each operator had the habit of improvising the way to make this final adjustment, consuming an excessive amount of time in this task. The project team has successfully developed and implemented fine-tuning standards for most machines. Each team leader became responsible for providing training to all members of his team in carrying out setups according to the new standards. The new daily routine for team leaders now includes the pre-preparation of all the tools needed for the setups according to the existing production plan for the day.

With these new routines and with operators trained in these new setup standards, the company started to save 440 min a day in setups, allowing that time to be used in value-added operations.

Another important change in the production and performance awareness among everyone was the introduction of team boards for teams of workers. The team boards helped in creating team spirit and performance awareness, since information about the team, KPI monitoring, and improvement suggestions' monitoring became part of the daily life of all workers.

4.3. Results at the End of the Project

The main improvements are marked in the VSM of Figure 5 using green star tags.

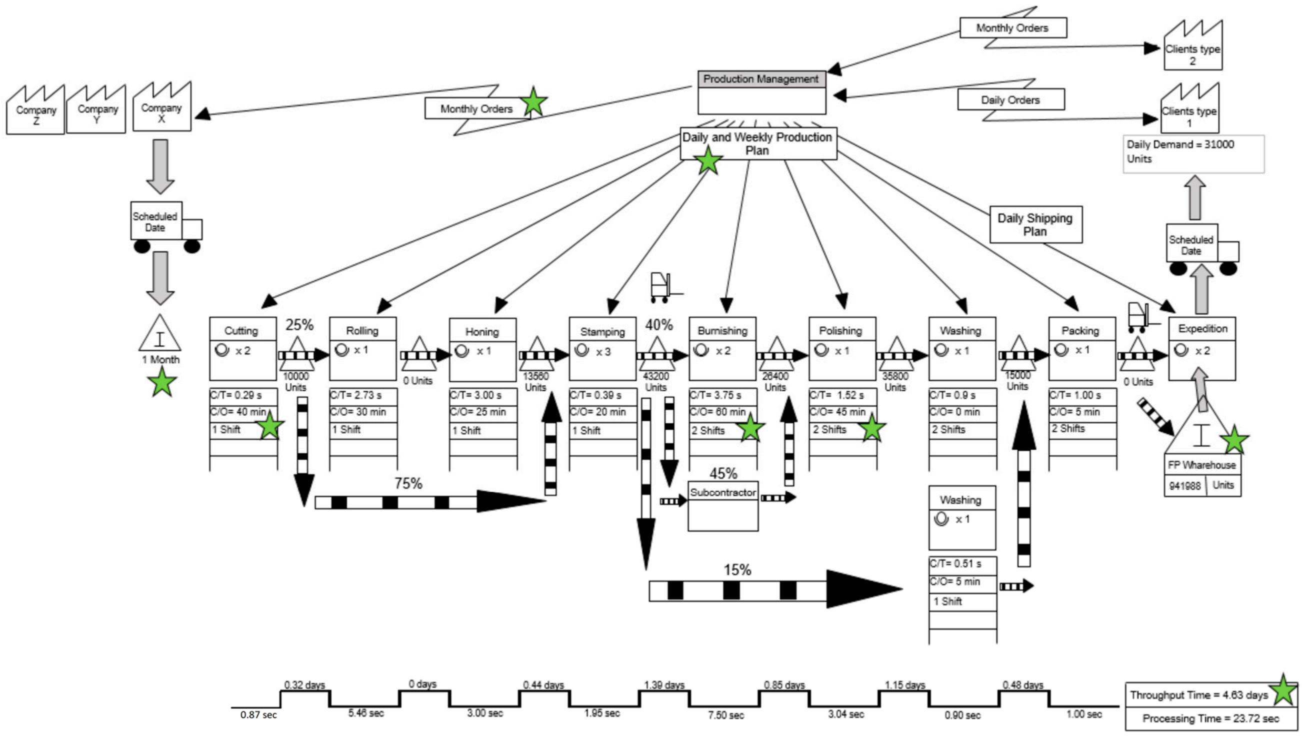

Figure 5. Final Value Stream Map.

The completion and follow-up of all production orders allowed a reduction from 667,415 to 225,600 units of WIP at the end of the project (Table 5). This reduction represents, in relative terms, a decrease of 66%, which is well above the 50% reduction that had been established as a target. The total throughput time for the spoons/forks family also followed a considerable reduction from 17.3 to 4.6 days. In terms of capital resources, there was a reduction of more than €255 k tied up in WIP. In practical terms, the company now has €255 k more available in capital than it had before.

Table 5. Key Performance Indicators behavior.

KIP and Objectives	Initial State	End of the Project	One Year Later
Total processing time for s&f * (s)	23.72	23.72	22.12
Total processing time for knives (s)	37.12	37.12	36.52
Daily Demand for s&f * (units)	31,000	31,000	35,000
Daily Demand for knives (units)	10,500	10,500	12,500
WIP of s&f * (50% reduction) (units)	537,045	143,960	175,000
WIP of knives (50% reduction) (units)	130,370	81,640	105,000
Total WIP (units)	667,415	225,600	280,000
Productivity (20% reduction) (units/man.h)	45.17	61.64	65.24
Finished products inventory (30% reduction) (units)	2,023,641	1,244,766	1,350,000
Throughput Time of s&f * (50% reduction)	17.3	4.6	5.0
Throughput Time of knives (50% reduction)	12.4	7.8	8.4
Value Added Ratio of s * f * (50% reduction)	0.0025%	0.0093%	0.0080%
Value Added Ratio of knives (50% reduction)	0.0054%	0.0086%	0.0079%

* spoons and forks.

After the implementation of the new stock management system, made available through the Excel file referred to in Section 4.2.2, the finished products warehouse now has 779,000 fewer units stored than before. This figure represents a reduction of over 38% in the quantity of products stored, exceeding the target of 30% set at the start of the project.

This project has brought about some changes in the way employees and leaders position themselves in the organization. There is now greater transparency and more effective communication between managers, supervisors, and employees, increasing the focus and collaboration of all on common goals. Weekly kaizen meetings and visual management have reduced the barriers between different departments and between different hierarchical levels.

The implementation of new standards in the machine setups has increased the time available for production by approximately 440 min.man each day. This, together with improvements in clarity and efficiency of planning and the reduction of WIP, led to an overall improvement in productivity by 36.5%, from 45.17 to 61.64 units/man.hour. This particular performance improvement clearly exceeded the 20% target initially set.

The good results were achieved mainly because of the management commitment, the expertise in Lean practices brought by the consultant and the low initial Value Added Ratio. This project brought clear transformations in waste awareness, work organization and the importance of continuous flow and low inventories, as well as transformations in the behavior and culture in the company. These ingredients are a significant step towards the company's operational excellence [58] and long-term sustainability [59]. Lean's inherent nature predicts that these adjustments will have a favorable impact on sustainability [60]. It became obvious from the study discussed in this article that the company enhanced its economic sustainability by lowering expenses and boosting competitiveness, as shown in Table 5. These accomplishments are directly related with the Sustainable Development Goal 8—"Decent work and economic growth", that includes policies encouraging productivity and promoting safe and secure working environments, and SDG 12—"Responsible Consumption and Production", that draws attention to the worldwide material consumption and therefore promotes the improvement of resource efficiency, and waste reduction. Because there was more teamwork, team spirit, a sense of belonging to a group, enhanced communication between employees, and a greater identification of the effort of each person in the performance of all, the social side of the socio-technical nature of organizations had a notable improvement.

Since the company became more resource-efficient, especially in terms of energy consumption per item produced and paper reduction accomplished through digitalization, this initiative had less of an environmental impact than anticipated.

4.4. Results One Year after the End of the Project

Once the project is finished, the big challenge is, at least, to maintain the changes implemented. The project team was aware of a huge percentage of companies implementing some transformations towards excellence, which fail to maintain them in the long term. For this reason, an analysis of the performance indicators was carried out one year after the end of the project, in January 2023. The behavior of the indicators is presented in Table 5. The figures shown in green indicate a positive trend, while those in red indicate a negative trend.

After the project was finished, the managers and supervisors tried to improve the performance of some machines and managed to reduce the processing times in the polishing operations in several products. They implemented changes in the machine that allowed 1 to 2 more products to be placed in each polishing comb, which reduced the total processing time. In the spoons/forks family the average reduction was 1.6 s per piece. On the knives family the reduction was a little shyer, only 0.6 s on average, because the improvement was only possible on a smaller number of models.

5. Discussion

WIP levels have depreciated somewhat, probably because daily production has increased to meet demand and with it an increase in batch sizes. Although it negatively affected WIP, this increase in production had a positive effect on productivity, as can be seen in Table 5. Throughput time, as well as value added ratio, followed the negative impact of WIP behavior, naturally.

The exceptional results achieved were possible due to the existence of some specific success critical factors, as well as the presence of some characteristics of the production unit at the beginning of the project. The main key success factor identified was the management commitment, as frequently referred as the number one factor in most literature. In this project that commitment played a key role in the success. This factor allowed another critical factor to enter the equation; an external consultant and a researcher with relevant knowledge and experience in adopting operational excellence principles and tools. These two critical success factors were essential in allowing the generation of a success momentum and the development of other success factors such as better communication, and leadership culture.

Despite the presence of these factors, the extraordinary level of success was only possible due to the initial characteristics of the production unit and the potential for improvement that existed. This is important because many other companies in similar situation could significantly improve their competitiveness and sustainability by replicating this method. The characteristics are, in short, a very low value in the Value Added Ratio due to: a culture of local optimization without a systemic view, focus on machine utilization (large batches to reduce setups), and push production.

In this study, the first two contextual factors expressed in the research question are very often mentioned in the literature on the successful implementation of Lean philosophy in industry, referred to earlier in Section 2. However, the third factor, 'very low Value Added Ratio (VAR)', is very rarely mentioned as a success factor, but is mentioned here because it is probably an important contribution of this work, as it shows that in this kind of context the possible gains are extraordinary. Other companies that find themselves in a similar context of very low VAR are in a position where they can make a leap to another level of competitiveness and sustainability.

6. Conclusions

The main goal of this study was to create and put into effect modifications that would enhance a cutlery company's overall production performance through the application of operational excellence ideas and practices. The mapping of the production process, using the VSM tool, made visible some of the problems and opportunities for improvement that became the focus of the study. The main problems identified were high levels of WIP, high levels of finished product stock, erratic production planning and control, long setups, poor communication between departments, and ineffective leadership.

The team created and implemented a number of changes, including pull production techniques, standard work, daily kaizen sessions, and visual management. The organization benefited from these changes in a number of ways, namely in terms of productivity, lead time, operating expenses, service, and increased information flow.

Some solutions in the area of digital transformation were necessary to achieve some of the objectives of this project, namely improving the flow of materials and reducing WIP. These results were achieved using low-cost technologies with simple computer applications developed internally and installed on tablets integrated into a network with the PPC system. This digitalization made it possible to reduce the use of paper and movement of people and greatly increased the effectiveness of communication between workers, supervisors, and company management. This made it possible to improve the efficiency of production planning and control and to reduce the errors that existed in communication and decision-making.

When comparing the project's final results with the initial set of objectives, it can be concluded that expectations were surpassed. WIP was reduced by 66.20% (reducing the value of inventory by 255,180.80 euros), throughput time was decreased by 73.4% for the spoons and forks family and by 45.16% for the knives family, and finished product stock was decreased by 38.49%. Productivity increased by 36.46%, far exceeding the defined target of 20%.

In summary, by increasing digitalization, optimizing processes, and improving resource utilization, companies can reduce their energy consumption, and consequently diminish their carbon footprint. Overall, the adoption of Digital Lean [61] and Lean & Green [62] approaches can help companies achieve operational excellence while minimizing their impact on the environment, making it an essential component of sustainable business practices [6].

One of the problems with implementations of this type of improvements is that they are usually difficult to maintain in the medium term. For this very reason, one year after the end of the project, the team returned to the field to evaluate the various performance indicators. It was interesting to note that stock levels increased slightly, both in WIP and stock of finished product. This behavior can be explained by a certain relaxation of people but can also be explained by a slight increase in demand. During that year, the people in the field managed to reduce very slightly the processing times in some operations and managed to improve quite significantly the productivity. That was one of the biggest surprises that left the team confident about the sustainability of the changes introduced because part of them became part of the culture.

These practices contribute to a successful Lean implementation by enabling organizations to streamline their processes, reduce costs, and improve customer satisfaction while also minimizing their impact on the environment. By integrating digital, Lean, and Green principles, organizations can create a culture of continuous improvement and achieve operational excellence in a sustainable manner, leading to long-term success.

Regarding the research question "It is possible to achieve great improvements in a lean and industry 4.0 implementation if three specific contextual factors are present in the company, namely (i) commitment of top management, (ii) knowledge on digitalization and lean, and (iii) very low Value-Added Ratio?" some considerations can be drawn. Outstanding results in terms of performance as described earlier are possible when the some of the classical critical factors are present but again the number one factor is the management commitment. With that factor in place all the other factors became possible, including enabling green, Lean and resilience sustained approaches [6]. Despite that, the outstanding results are only possible when the production unit has a large improvement potential, characterized by a low value added ratio (in this case way below 0.1%).

The three main contributions of this study are: (i) the confirmation of the role of top management commitment in the success of this type of change and (ii) for the performance improvement to be extraordinary, there must be great potential for improvement, translated into a very low Value Added Ratio, and (iii) somebody with experience in Lean implementation is needed so successful improvement actions are implemented.

The circumstance that this work was carried out in a single company is obviously a limitation of this study. However, this happened because the origin of all this work is found in a master's project developed in the company CR in particular. In any case, this paper showed a concrete industrial case in which the existence of the three contextual factors already mentioned was indeed decisive for the achievement of exceptional improvements in the performance of the production system, thus positively answering the research question.

Another limitation of this study is that when VAR is not very low, even if the first two critical factors are met the potential of improvement is more limited. In other words, as the VAR increases, the potential for performance improvement decreases.

One of the ideas for future research is to identify in more detail the steps that need to be taken in such a transformation in order to achieve significant improvements in performance more quickly and sustainably.

Author Contributions: Conceptualization, J.D.-C., R.M.S., H.M., R.M.L. and I.M.; validation, J.D.-C., R.M.S. and I.M.; formal analysis, J.D.-C., R.M.S. and I.M.; investigation, J.D.-C. and I.M.; data curation, I.M.; writing—original draft preparation, J.D.-C. and I.M.; writing—review and editing, J.D.-C., R.M.S., H.M. and R.M.L.; supervision, J.D.-C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: This work has been supported by FCT—Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ohno, T. *Toyota Production System: Beyond Large-Scale Production*; Productivity, Inc.: New York, NY, USA, 1988.
2. Womack, J.; Jones, D. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*; Fee Press: New York, NY, USA, 1996.
3. Miller, R. *The Shingo Model for Operational Excellence*; Jon M. Huntsman School of Business: Logan, UT, USA, 2016; p. 45.
4. Liker, J. *Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*; McGraw-Hill Education: Madison, WI, USA, 2004.
5. Kingman, J.F.C. The single server queue in heavy traffic. In *Mathematical Proceedings of the Cambridge Philosophical Society*; Cambridge University Press: Cambridge, UK, 1961; Volume 57, pp. 902–904.
6. Touriki, F.E.; Benkhati, I.; Kamble, S.S.; Belhadi, A.; El Fezazi, S. An integrated smart, green, resilient, and lean manufacturing framework: A literature review and future research directions. *J. Clean. Prod.* **2021**, *319*, 128691. [CrossRef]
7. Leong, W.D.; Teng, S.Y.; How, B.S.; Ngan, S.L.; Rahman, A.A.; Tan, C.P.; Ponnambalam, S.; Lam, H.L. Enhancing the adaptability: Lean and green strategy towards the Industry Revolution 4.0. *J. Clean. Prod.* **2020**, *273*, 122870. [CrossRef]
8. Rauch, E.; Dallasega, P.; Matt, D.T. Critical Factors for Introducing Lean Product Development to Small and Medium sized Enterprises in Italy. *Procedia CIRP* **2017**, *60*, 362–367. [CrossRef]
9. Siegel, R.; Antony, J.; Garza-Reyes, J.A.; Cherrafi, A.; Lameijer, B. Integrated green lean approach and sustainability for SMEs: From literature review to a conceptual framework. *J. Clean. Prod.* **2019**, *240*, 118205. [CrossRef]
10. United Nations. *Sustainable Development Goals—Teaching Guide and Resources*; United Nations: New York, NY, USA, 2018.
11. United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2016; p. 36. [CrossRef]
12. Womack, J.; Jones, D.; Roos, D. *The Machine that Changed the World*; Fee Press: New York, NY, USA, 1990.
13. Krafcik, J.F. Triumph of the lean production system. *Sloan Manag. Rev.* **1988**, *30*, 41–52. [CrossRef]
14. Liker, J.; Franz, J. *The Toyota Way to Continuous Improvement: Linking Strategy and Operational Excellence to Achieve Superior Performance*; McGraw-Hill Publishing: New York, NY, USA, 2011.
15. Shingo Institute. The Shingo Model. 2020. Available online: https://shingo.org/shingo-model/ (accessed on 8 June 2020).
16. Plenert, G.J. *Discover Excellence: An Overview of the Shingo Model and Its Guiding Principles*; CRC Press: New York, NY, USA, 2017.
17. Rother, M.; Shook, J. *Learning to See: Value Stream Mapping to Add Value and Eliminate Muda*; The Lean Enterprise Institute: Cambridge, MA, USA, 1999.
18. Dinis-Carvalho, J.; Moreira, F.; Bragança, S.; Costa, E.; Alves, A.; Sousa, R. Waste identification diagrams. *Prod. Plan. Control* **2015**, *26*, 1–13. [CrossRef]
19. Dinis-Carvalho, J.; Guimaraes, L.; Sousa, R.M.; Leão, C.P. Waste identification diagram and value stream mapping. *Int. J. Lean Six Sigma* **2019**, *10*, 767–783. [CrossRef]
20. Kumar, S.; Harms, R. Improving business processes for increased operational efficiency: A case study. *J. Manuf. Technol. Manag.* **2004**, *15*, 662–674. [CrossRef]
21. Sanchez-Ruiz, L.; Blanco, B. Business, How Do Companies Implement Process Management? The Case of Cantabrian Companies. *Bus. Manag. Econ. Res.* **2016**, *2*, 1–9.
22. Rother, M. *Toyota KATA: Managing People for Improvement, Adaptiveness and Superior Results*; McGraw-Hill Education—Europe: New York, NY, USA, 2010.
23. Brajer-Marczak, R. Employee engagement in continuous improvement of processes. *Management* **2014**, *18*, 88–103. [CrossRef]
24. Moica, S.; Harea, C.V.; Marian, L. Effects of Suggestion System on Continuous Improvement: A Case Study. In Proceedings of the 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bangkok, Thailand, 16–19 December 2018; pp. 592–596. [CrossRef]
25. Dinis-Carvalho, J.; Ratnayake, R.M.C.; Stadnicka, D.; Sousa, R.M.; Isoherranen, J.V.; Kumar, M. Performance enhancing in the manufacturing industry: An improvement KATA application. In Proceedings of the 2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bali, Indonesia, 4–7 December 2016; pp. 1250–1254. [CrossRef]
26. Ortiz, C.A. *The TPM Playbook: A Step-by-Step Guideline for the Lean Practitioner*; Productivity Press: Boca Raton, FL, USA, 2016.
27. Hu, Q.; Mason, R.; Williams, S.J.; Found, P. Lean implementation within SMEs: A literature review. *J. Manuf. Technol. Manag.* **2015**, *26*, 980–1012. [CrossRef]
28. Ribeiro, L.; Alves, A.C.; Moreira, J.F.P.; Ferreira, M. Applying standard work in a paint shop of wood furniture plant: A case study. In Proceedings of the 22nd International Conference on Production Research, Parana, Brazil, 28 July–1 August 2013.
29. Rodrigues, J.; Sá, J.C.; Silva, F.J.G.; Ferreira, L.P.; Jimenez, G.; Santos, G. A Rapid Improvement Process through "Quick-Win" Lean Tools: A Case Study. *Systems* **2020**, *8*, 55. [CrossRef]

30. Wong, Y.C.; Wong, K.Y.; Ali, A. A study on lean manufacturing implementation in the Malaysian electrical and electronics industry. *Eur. J. Sci. Res.* **2009**, *38*, 521–535.
31. Zhou, B. Lean principles, practices, and impacts: A study on small and medium-sized enterprises (SMEs). *Ann. Oper. Res.* **2012**, *241*, 457–474. [CrossRef]
32. Powell, D.J.; Romero, D. Digital Lean Manufacturing: A Literature Review. In Proceedings of the 2021 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Singapore, 18–21 December 2021; Volume 2, pp. 659–662. [CrossRef]
33. Raguseo, E.; Vitari, C. Investments in big data analytics and firm performance: An empirical investigation of direct and mediating effects. *Int. J. Prod. Res.* **2018**, *56*, 5206–5221. [CrossRef]
34. AlMulhim, A.F. Smart supply chain and firm performance: The role of digital technologies. *Bus. Process. Manag. J.* **2021**, *27*, 1353–1372. [CrossRef]
35. Gong, C.; Ribiere, V. Developing a unified definition of digital transformation. *Technovation* **2020**, *102*, 102217. [CrossRef]
36. Abualfaraa, W.; Salonitis, K.; Al-Ashaab, A.; Ala'raj, M. Lean-Green Manufacturing Practices and Their Link with Sustainability: A Critical Review. *Sustainability* **2020**, *12*, 981. [CrossRef]
37. Khalid, B.; Naumova, E. Digital transformation SCM in view of COVID-19 from Thailand SMEs perspective. *Glob. Chall. Digit. Transform. Mark.* **2021**, *Chapter 4*, 49–66.
38. Thekkoote, R. A framework for the integration of lean, green and sustainability practices for operation performance in South African SMEs. *Int. J. Sustain. Eng.* **2022**, *15*, 47–58. [CrossRef]
39. Thanki, S.; Govindan, K.; Thakkar, J. An investigation on lean-green implementation practices in Indian SMEs using analytical hierarchy process (AHP) approach. *J. Clean. Prod.* **2016**, *135*, 284–298. [CrossRef]
40. Teixeira, P.; Sá, J.; Silva, F.; Ferreira, L.; Santos, G.; Fontoura, P. Connecting lean and green with sustainability towards a conceptual model. *J. Clean. Prod.* **2021**, *322*, 129047. [CrossRef]
41. Belhadi, A.; Touriki, F.E.; El Fezazi, S. Benefits of adopting lean production on green performance of SMEs: A case study. *Prod. Plan. Control* **2018**, *29*, 873–894. [CrossRef]
42. Graban, M. Notes from Meeting Masaaki Imai. LeanBlog, 2012. Available online: https://www.leanblog.org/2012/06/meeting-mr-imai/ (accessed on 13 April 2021).
43. Mishra, M.N. Identify critical success factors to implement integrated green and Lean Six Sigma. *Int. J. Lean Six Sigma* **2018**, *13*, 765–777. [CrossRef]
44. Stankalla, R.; Koval, O.; Chromjakova, F. A review of critical success factors for the successful implementation of Lean Six Sigma and Six Sigma in manufacturing small and medium sized enterprises. *Qual. Eng.* **2018**, *30*, 453–468. [CrossRef]
45. Qureshi, K.M.; Mewada, B.G.; Alghamdi, S.Y.; Almakayeel, N.; Qureshi, M.R.N.; Mansour, M. Accomplishing Sustainability in Manufacturing System for Small and Medium-Sized Enterprises (SMEs) through Lean Implementation. *Sustainability* **2022**, *14*, 9732. [CrossRef]
46. Puram, P.; Sony, M.; Antony, J.; Gurumurthy, A. A conceptual framework for a systemic understanding of barriers during lean implementation. *TQM J.* **2021**, *34*, 1469–1484. [CrossRef]
47. Porter, M.E.; van der Linde, C. Toward a New Conception of the Environment-Competitiveness Relationship. *J. Econ. Perspect.* **1995**, *9*, 97–118. [CrossRef]
48. Elkington, J. *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*; Wiley: Oxford, UK, 1997.
49. Schaltegger, S.; Wagner, M. Sustainable entrepreneurship and sustainability innovation: Categories and interactions. *Bus. Strategy Environ.* **2011**, *20*, 222–237. [CrossRef]
50. Linnenluecke, M.K.; Griffiths, A. Corporate sustainability and organizational culture. *J. World Bus.* **2010**, *45*, 357–366. [CrossRef]
51. Souza, T.A.; Vaccaro, G.L.R.; Lima, R.M. PSCPF: Planning, scheduling and control of patient flow. *Production* **2021**, *31*, 1–14. [CrossRef]
52. Tébar-Rubio, J.V.; Ramírez, F.J.; Ruiz-Ortega, M.J. Conducting Action Research to Improve Operational Efficiency in Manufacturing: The Case of a First-Tier Automotive Supplier. *Syst. Pract. Action Res.* **2023**, *36*, 427–459. [CrossRef] [PubMed]
53. Coghlan, D.; Brannick, T. *Doing Action Research in Your Own Organization*, 4th ed.; SAGE: London, UK, 2014.
54. Rother, M. *The Toyota Kata Practice Guide: Practicing Scientific Thinking Skills for Superior Results in 20 Minutes a Day*; McGraw-Hill Education: New York, NY, USA, 2017.
55. Little, J.D.C. A Proof for the Queuing Formula: $L = \lambda W$. *Oper. Res.* **1961**, *9*, 383–387. [CrossRef]
56. Beecroft, G.D.; Duffy, G.L.; Moran, J.W. *The Executive Guide to Improvement and Change*; Qualilty Press: Milwaukee, WI, USA, 2003.
57. Productivity Press Development Team. *Just-in-Time for Operators (The Shopfloor Series)*; Productivity Press: New York, NY, USA, 1998.
58. Naftanaila, I.; Radu, C.; Cioana, G. Operational Excellence—A Key to World-Class Business Performance. *Stud. Bus. Econ.* **2013**, *8*, 133–141.
59. Purvis, B.; Mao, Y.; Robinson, D. Three pillars of sustainability: In search of conceptual origins. *Sustain. Sci.* **2018**, *14*, 681–695. [CrossRef]
60. García-Alcaraz, J.L.; García, A.S.M.; Díaz-Reza, J.R.; Macías, E.J.; Lardies, C.J.; Fernández, J.B. Effect of lean manufacturing tools on sustainability: The case of Mexican maquiladoras. *Environ. Sci. Pollut. Res.* **2022**, *29*, 39622–39637. [CrossRef]

61. Martinho, R.; Lopes, J.; Jorge, D.; de Oliveira, L.C.; Henriques, C.; Peças, P. IoT Based Automatic Diagnosis for Continuous Improvement. *Sustainability* **2022**, *14*, 9687. [CrossRef]
62. John, L.; Sampayo, M.; Peças, P. Lean & Green on Industry 4.0 Context—Contribution to Understand L&G Drivers and Design Principles. *Int. J. Math. Eng. Manag. Sci.* **2021**, *6*, 1214–1229. [CrossRef]